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ELECTRICITY FROM PEAT GAS.

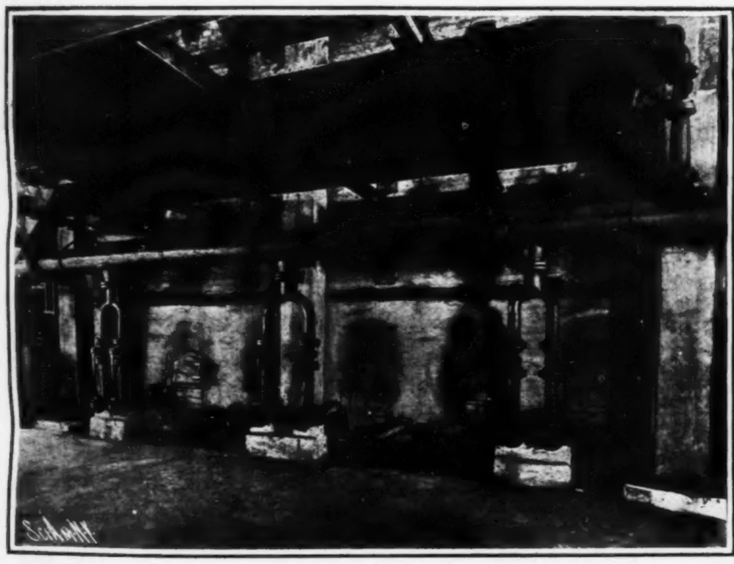
By the English Correspondent of the Scientific American.

A comprehensive and extensive scheme for the supply of electricity both for power and lighting purposes from peat gas is being projected in Ireland. The scope of the project is to install a large central station on the fringe of the famous bog of Allen in County Kildare, upon the banks of the Grand Canal 24 miles from Dublin, and to transmit the energy thus produced throughout the area of Kings County and Kildare. With the inexhaustible supplies of peat thus immediately available power gas will be produced for driving large electrical generators by high-powered gas engines, together with the recovery of the attendant by-products comprising sulphate of ammonia, peat-tar, etc., for which a ready market is available.

The process to be adopted is that perfected by Herr Martin Ziegler, the German engineer whose name is well known in connection with the distillation of lignites in Germany. Herr Ziegler has been experimenting and perfecting his process for several years past both in the manufacture of peat coke and peat gas. An extensive plant has been established at Beuerberg, Bavaria, to carry out Herr Ziegler's inventions. The plant, which is situated on the borders of an extensive peat bog 28 miles south of Munich on the Loisach River, is devoted to the manufacture of both peat coke and peat gas, together with a complete plant for the treatment of the by-products. Peat coke, owing to its high calorific value, and its applicability in lieu of charcoal to metallurgical processes, is in great demand. It is being extensively utilized by the German navy, for which it is eminently adapted because it is smokeless; by armament manufacturers as an excellent hardening medium for armor plates, and by manufacturing chemists for the production of calcium carbide and in various chemical processes.

In the preparation of this product the peat after being cut from the bog is fed into a press from which it issues in continuous strings or rolls through nozzles. These are cut into conveniently sized pieces and taken to the drying field, where within a few days the external surface becomes so hardened as not to be appreciably affected by rain. The clods are left exposed to the air for some three weeks, when they are piled into heaps and again left for a prescribed period. The effect of this exposure is to cause the elimination of about 75 per cent of the moisture contained in the raw article.

Drying completed, the peat is conveyed to the furnaces in trucks where it is transported on conveyers to the top floor of the building and dumped into the furnaces, which are vertical kilns 40 feet high, almost semi-circular in section. The furnace or retort is completely surrounded by flues through which pass gases heated to a temperature of 1,832 deg. F., the temperature of the retort itself, however, not rising above 1,000 deg. F. The furnaces are fired with peat. The gases driven off in distillation (which in this process really constitute a by-product, as the peat coke is the desired article) are conducted through suitable pipes to



LOWER GAS FURNACES.

HOPPERS INTO WHICH THE PEAT IS DUMPED.

TAR DISTILLERY.

COKE OVEN BUILDING.

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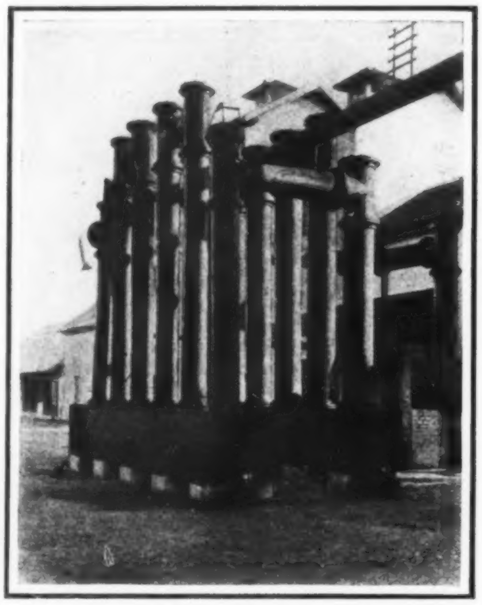
the plant for the recovery of the oils and tars. During charging, and whenever it is desired to keep air out of the retorts, jets of steam are directed thereinto. Coking occupies about eighteen hours and from 8 to 10 tons of the product can be manufactured in the course of twenty-four hours. As the raw peat, owing to its prolonged exposure to the air, has become thoroughly hardened, it does not crumble while in the retort, and is consequently drawn off at the base of the kiln into trucks fitted with lids, run out into the yard, and allowed to cool, which occupies about eight hours, when the article is ready for sorting.

If the climatic conditions are not favorable to sufficient drying of the crude peat, the latter is fed into a different type of retort where it is turned into half coke, with a proportionately greater yield of peat gas and chemical products. In this case the retorts are not surrounded by flues, but the gases are discharged direct into the kiln for the purpose of drying and gasifying the contents. The moisture in the peat is first driven off, followed by the tar-charged vapors and gases, which are collected. While the latter are not particularly rich, they are suitable for gas engines.

In the Irish installation the production of power gas is the chief consideration, and this is probably the most valuable feature of the Ziegler process, at any rate so far as the northern temperate climes are concerned, since the climatic conditions for air-drying the peat are for the most part confined to three or four months during the year. The advantage of peat gas production lies in the fact that peat with a moisture proportion of approximately 50 per cent is most suitable for the power gas, the moisture becoming an essential ingredient of the water gas and preventing too rapid combustion. Consequently it is only necessary to submit the peat after its removal from the bog to a partial drying. The material in this condition contains sufficient chemical constituents not required for the gas to produce by their removal and sale an amount approximately equivalent to the cost of the fuel required for the production of the gas. The type of furnaces at the Beuerberg works in which this process is carried out is the joint invention of Messrs. Ziegler, F. Fleiss, and H. Reddig, and the first furnace of its type was erected by the second named inventor in eastern Prussia at the Fleiss iron and steel works where it demonstrated its efficiency and value. The kiln is of special design, having two contractions extending all around it. At the bottom is the grate of small section and jacketed, followed by a wider section, then a narrow belt and finally another wider section extending to the top which is sealed by the feeder hopper and the conduit through which the gases escape. The grate section is square and is fitted with openings on all four sides inside the jacket. The grate area is disposed around the bottom of the kiln with various vertical and horizontal orifices and air passages communicating with the interior of the retort. The air is conducted to within the kiln through the ash pit and grate, while the former vertical and horizontal passages are accessible only through the fire doors.

The gas produced by this process is of good quality and eminently adapted to gas engines. It was tested for some weeks in the driving of an internal combustion motor and was found to produce scarcely any deposit. It was determined as a result of this test that 2.2 pounds of air-dried peat containing 25 per cent of moisture gave 1 horse-power-hour.

For the recovery of the residual products the installation is also of special design. The gases are withdrawn from the kilns through two conduits, the pressure being so regulated that a slight vacuum is always maintained within the retort. After leaving the latter the vapors pass through a series of box condensers on



CONDENSATION APPARATUS FOR TAR AND WATER.

which pans are placed, the dilute solutions of sulphate of ammonia and calcium acetate being evaporated therein. The two conduit systems then effect a junction and pass through condenser columns where the tar and tar-water collect. If desired the gases can be burned directly or discharged into the open air through the smokestacks.

The tar water and tar empty into a large tank, whence they are elevated by pumps into the still, where with the assistance of steam the tar and tar water are separated. The latter is neutralized with lime while the ammonia and methylated spirits are together driven off. This concentrate is then subjected to redistillation, the ammonia being absorbed by sulphuric acid and the alcohol as a raw 36-per-cent spirit which by further rectification can be converted into a 96-per-cent methyl alcohol. The sulphate of ammonia is crystallized in pans and the parent liquid together with the acetate are further evaporated in the pans previously mentioned.

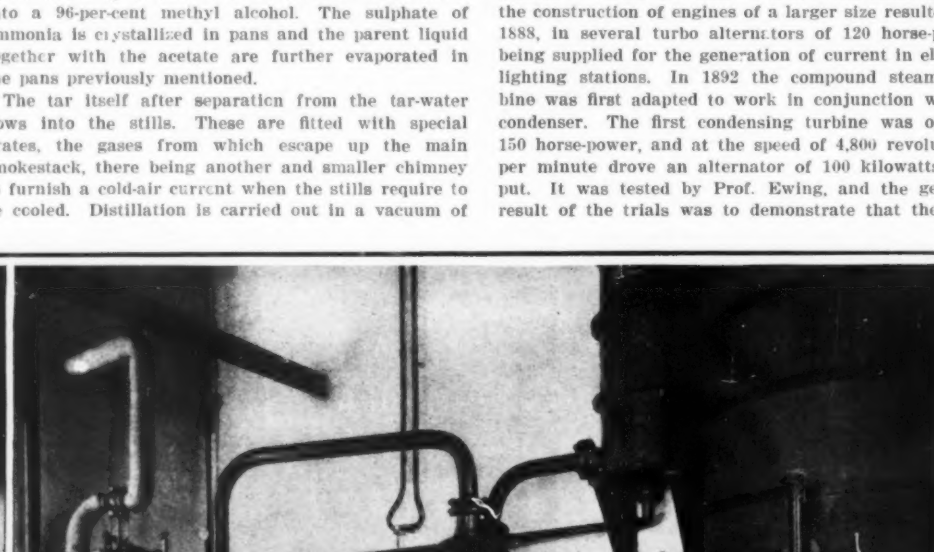
The tar itself after separation from the tar-water flows into the stills. These are fitted with special grates, the gases from which escape up the main smokestack, there being another and smaller chimney to furnish a cold-air current when the stills require to be cooled. Distillation is carried out in a vacuum of 0.8-inch of water. The light oils which first escape are collected as raw oil; then follow the kerosene oil and vaseline and solid matter. The residue thus left is practically pure carbon and is available for making electric light carbons. The gases which escape during distillation are either conveyed to the grates or else permitted to escape into the chimney.

The kerosene oil secured is ejected into a basin where it is separated from the moisture combined therewith, subsequently being passed into the cooling apparatus comprising a series of cylinders disposed in rows in a pit fitted with Venetian blinds. In the course of a few days the grease becomes solid, when the cylinders are emptied, the greasy mass being disintegrated and the oil removed by suction. By passing the dried mass through compressors the white and odorless paraffine wax is secured. The oil withdrawn from the paraffine is combined with the light oils already described and the mixture is available as a gas oil for the production of oil gas.

It will be observed that all the most valuable residual products are secured by the process and they find a ready market at prices which are not liable to severe fluctuation, since the demand is greater than the supply. So far as the Irish scheme is concerned the latter will constitute an important feature of the enterprise, since several chemical companies have already undertaken to acquire the necessary land for works in close proximity to the central station. Owing to the low cost at which the peat gas is manufactured it will enable electric energy to be supplied at a very low figure. Power will be supplied in bulk to the various industries and corporations, the latter of which will in many cases furnish the requisite current for lighting purposes, which the generating concern will not do. The success of the Beuerberg installation, which has been visited by numerous European engineers interested in the utilization of peat, has demonstrated that it offers a commercially successful solution to the problem.

At the Royal Institution Mr. Gerald Storey, B. E., M. I. C. E., delivered the first of two lectures on "The Development of the Modern Turbine and Its Application." In the development of the transmission of power from central stations the steam turbine had, he said, taken a notable part, and had practically ousted the reciprocating engine in all large sizes. He did not know at the present time of a single reciprocating engine of large size being put down either in this country or on the Continent. The origin of the great development of the steam turbines on land dated from 1884, when Mr. Parsons first made his steam turbine of about 10 horse-power. Mr. Storey gave a detailed description of the old Parsons steam turbine, and pointed out that the efforts which were made toward the construction of engines of a larger size resulted, in 1888, in several turbo alternators of 120 horse-power being supplied for the generation of current in electric lighting stations. In 1892 the compound steam turbine was first adapted to work in conjunction with a condenser. The first condensing turbine was one of 150 horse-power, and at the speed of 4,800 revolutions per minute drove an alternator of 100 kilowatts output. It was tested by Prof. Ewing, and the general result of the trials was to demonstrate that the con-

COLUMN APPARATUS FOR OBTAINING ACETATE OF LIME.



STILL IN THE ALCOHOL RECTIFICATION DEPARTMENT.

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densing steam turbine was an exceptionally economical heat engine. The result marked an era in the development of the steam turbine, and opened for it a wide field, including some of the chief applications of motive power from steam. As a result, at about that period, turbine alternators of the condensing type were placed in Newcastle, Cambridge and Scarborough electric supply station. These steam turbines were of the radial flow type, which had been adopted in 1891 on account of the temporary loss of the patents, but on the recovery of these, in 1894, the parallel flow type was reverted to, with considerable improvements in design, increasing the economy and decreasing the cost of manufacture. The first large turbines of this improved type were of 350 kilowatts. Turbo alternators were supplied to the city of Elberfeld in Germany, which were tested by a committee of German experts. Within the last twelve years the output of the Parsons steam turbine had gone up by leaps and bounds, until there were now about 2,500,000 horse-power on land of this turbine at work and on order. Practically the whole of the great power distribution scheme in the northeast of England at Newcastle was supplied with these steam turbines. It might be said that without the development of the high-speed dynamo and alternator there would have been no steam turbine such as we knew to-day.

ELECTRICITY IN MINE TRANSPORTATION.

A NEW FACTOR.

To most men who have become accustomed to the multifold uses of electricity upon the surface of the earth, its importance far underground is unknown. Yet, just as electricity has changed the whole complexion of life above ground, so is it bringing about a revolution in the operation of the mines that supply the country with fuel. Where there was one electric locomotive in the anthracite coal mines of Pennsylvania a decade ago, there are a dozen now; the hundreds of feet of trolley wire have grown into thousands. Millions of dollars have been spent upon the electric locomotives, the power houses and the strengthening of tracks necessary to the improved system.

The network of the tracks in the anthracite mines has spread until the underground mileage is almost as great as the mileage of the so-called "anthracite roads" on the surface. With every year the gangways are extended farther from the shafts; and with the increasing length of hauls the problems of underground transportation become more serious. The result is that the operation of a coal mine nowadays includes the operation of a railroad system with intricacies and difficulties peculiar to itself.

Some 17,000 horses and mules are still employed in and around the anthracite mines, but in many cases mere distance has disqualified mule-power. Compressed air locomotives, though used in considerable number, have proven less economical than electric locomotives, and their use is not apt to be extended. There are few steam locomotives in the mines, and there will be still fewer in the future. Combustion in any form is not desirable in coal mines, on account of the risk of gas explosions.

Within three years, 1903 to 1906, the number of electric locomotives in the anthracite mines—this does not include those at the top of the shafts—grew from 84 to 205. There were only 41 locomotives operated by steam in 1906 as against 49 in 1903, a decrease of 16 per cent. Compressed air locomotives increased from 67 to 104 in the three years.

FOUR KINDS OF MOTIVE POWER.

Thus there are four separate and distinct kinds of motive power, exclusive of the rope haulage for steep slopes, used in the mines: mules, steam, compressed air, electricity. In the volume of work done, mules, at this time, remain far in the lead. Steam is going backward. Compressed air is about stationary, probably destined to lose its importance in the future. Electricity is the coming factor; it will make headway steadily.

Managers of anthracite coal mining companies say that the mules will never be eliminated altogether. There will always be certain kinds of work which can be done more satisfactorily and more economically by animal muscle than by any form of mechanical power. In the gangways producing small quantities of coal the installation of electricity would be impracticable and wasteful.

Every one of the several kinds of motive power has greatly increased in expense in recent years. A mine mule that cost $125 in 1897, cost $240 in 1907. The rise in the prices of materials ran up the cost of installing mechanical appliances. The lengthening of the gangways and the exhaustion of the more accessible veins of coal, however, have been the greatest factors, for they have caused a direct increase in the amount of hauling to be done; and transportation in the mines may be expected to become a more and more costly part of coal mine operation as time passes.

If, as mining got deeper and more difficult, only the old methods had been employed, the cost of production would have so increased that the price of coal to the consumer would have had to be raised. The resources of the mining companies have enabled them to install electric haulage systems which are not possible in the case of the small individual operators. And, though the cost of mine transportation must increase, the economy effected by the expenditures upon electric installation tends to keep down and steady the retail price.

THE MULES.

Picked specimens of mule flesh are brought from every part of the country to the anthracite region in northeastern Pennsylvania. The character of the work is such that only the strongest animals are available. The demand began to press so hard upon the supply toward the end of the last century that the price jumped rapidly. One company found, at the end of 1907, that the average cost of mules had been $210, while it had only been $145 in 1900. In one year this same company lost mules to the value of $50,000 from sickness and other causes.

Stables are fitted up underground, and when a mule goes down into a mine he usually goes to spend the rest of his life there. He has to be well taken care of if he is to do the work properly. In the newer mines he has stables of concrete (except the floors, which must not be hard for his feet), lighted by electricity, with perfect drainage and ventilation. Sanitary conditions are better in a mine stable than in the average stable above ground.

The cost of maintaining one mule one day comes to about 80 cents. The expense of feeding has gone up 35 per cent in the last five years. The statistics of several anthracite mines show that a mule consumes in a day 10.61 pounds of hay and 9.37 pounds of corn and oats. This is one of the costs that continues during the suspension of work as at other times, for the mule must eat whether the coal is being mined or not.

COMPRESSED AIR FOR HAULING.

When it became advisable to substitute mechanical power for mules, compressed air locomotives were adopted because they were secure against fire or explosion of gas. Furthermore, they were low and could get through gangways which were not high enough even for mules. Comparatively simple in their working, they did not require much training in operating them.

But the cost of operation is very large. Along the course over which the locomotive travels are charging stations, at any one of which the tanks that form part of the locomotive may be filled. The air is compressed, first, to 800 or 900 pounds per square inch—or maybe less—and is transferred from the pipes to the locomotive at, say, 125 pounds. The waste, in manufacturing unused power, is enormous.

The distance which an air locomotive can travel without replenishing depends upon the capacity of the tanks. A mile and a half is a long journey for a single charge. Smaller locomotives cannot go more than half a mile. The compressor in the power house above ground has to be going all the time. The tanks have a capacity of from forty to more than two hundred cubic feet, all according to the type of locomotive. The locomotive may weigh ten or twelve thousand pounds, it may weigh fifty thousand. One may be able to haul a hundred tons up a three per cent grade, another twenty-five tons.

The managers of anthracite mining companies found, after thorough trials, that air locomotives were less economical than those run by electricity. But that does not mean that compressed air is to be abandoned, because there are certain conditions which demand it. It is in very gaseous mines, principally, that compressed air is superior to other forms of power. It is absolutely safe so far as fire is concerned. Some have said that electricity can be used with absolute safety, too, but that is not universally agreed. Hence, the air locomotive will always find a place in some of the mines where gas is apt to be thick. There is one mine in the anthracite region, for example, in which compressed air does all the hauling. The two locomotives are supplemented by one mule, which does some odds and ends of work near the bottom of the shaft. On the other hand, one of the important mining companies has not a single air locomotive, employing electricity exclusively for its mechanical hauling.

ELECTRIC LOCOMOTIVES.

The first electric mine locomotive was built in 1887. At that time it was a startling innovation, and general doubt as to its usefulness was expressed. In appearance it was very unlike the one of to-day. Among other things, its height was too great for the low gangways found in many mines. It looks as clumsy compared to its modern successor as the model of the first railway locomotive beside the gigantic machines turned out from the shop in the year 1907.

Some of these early creations, however, have lasted straight through the period of improvement and are still in operation. One such was built in 1889. At the time of the Pan-American Exposition, in Buffalo, the officials whose duty it was to gather exhibits for the Electrical Building, decided to obtain this locomotive. They wrote to the manager of the mine where it had been used, to ask if it could be "resurrected from the scrap heap." The manager replied, with some indignation, that it could not be "resurrected from the scrap heap," being still in operation, but that it could be loaned, provided a new locomotive were to be substituted to do the work during its absence.

In the early nineties came the "terrapin back," more nearly approaching the squat machine now in general use. Like the type that preceded, it was equipped with one motor and the axles were coupled together by connecting rods. Then came the locomotive with two motors, the axles being driven independently. In general character this is the locomotive of the present day.

Without abandoning any of the already established methods of transportation, the anthracite mining companies have made great outlays upon the installation of electricity within the last decade. The use of the new force brought with it the employment of a new class of skilled labor and the necessity of improving the tracks to bear heavier loads. The mobilization of longer trains of mine cars than the mules could haul has tended to greater complexity of operation.

"In our mines," one general manager said recently, "the hauls, some of them at least, are getting entirely too long for mules. I know of one haul that is as long as three miles; it is three miles, that is, from the 'breast' where the coal is mined, through the gangways, to the shaft. It is getting simply impossible to manage such a proposition as that with mules. We have tried compressed air, but now we've decided that electricity is the best. It is not likely that this company will ever buy another air locomotive. We are adding to our supply of electric locomotives every year."

Electricity demands a much firmer and stronger track than does the mule. Manufacturers of electric locomotives invariably urge the adoption of heavier rails. "For animal and rope hauling," says one, "the prevailing light rails are satisfactory. But for the locomotive of traction haulage the rails should be much heavier—in fact, the heavier the better." With the miles of track that have to be laid this means great expense. For a ten-ton locomotive, a rail weighing 25 pounds to the yard is prescribed as a minimum, but a 45-pound rail is recommended.

Electric traction introduces new engineering tasks in the matter of grades. With the mules there does not have to be any such fixed, mathematical rule governing the grade—for the number of mules can be increased at certain places, according to requirements. But the capabilities of a locomotive are the same at all times, and grades have to be reduced accordingly. It is the adverse grades that determine the size of a locomotive in any particular mine. Though they can climb a 12 per cent, or even a 15 per cent grade, with heavy rails, the locomotive cannot be called upon to perform economically, on long runs, against grades of more than 3 per cent. Consequently, there has had to be a great deal of work toward leveling the floors in the gangways.

When mechanical power supplants mules, the bonding of the rails becomes at once an important factor in mine transportation. The bonds must be carefully inspected, and, when they are loose, tightened or replaced. At the sharp curves in the mines provision has to be made for the increased track resistance. The outer rail has to be elevated as on regular railroads on the surface.

In a mine gangway the location of the trolley wire is not as simple a matter as it is on the streets and on country roads, for space is very limited. The wire must be installed in such a manner that it will cause the least possible interference with free passage of men and animals. The character of the overhead work has an important bearing upon the successful opera-

tion of the locomotive. A man of thorough experience has to supervise the installation.

A mine haulage system has to have a regular schedule, just like a street railway or a subway. If one locomotive is going from the shaft with a train of "empties" while another goes toward it with a loaded train, it means a saving in the size of generator and engine. Keeping such schedules involves employing well-paid men, who are capable of running things smoothly and avoiding the confusion which means loss of time and loss of money.

One needs only to make a visit to the mines to see how the whole aspect of mining has been changed by the introduction of electricity. It is not merely the purchase of the locomotive and trolley wires, but the creation of numerous correlative expenses that makes of mechanical traction a problem to trouble the mine manager. It is a form of expenditure which does not bring in any direct income, but which has to be incurred. It is made a necessity because of the exhaustion of the easily accessible veins of coal.

ELEMENTS OF ELECTRICAL ENGINEERING.—XXII.

STORAGE BATTERIES. PART I. THEORY AND CONSTRUCTION.

BY A. E. WATSON, E.E., PH.D., ASSISTANT PROFESSOR OF PHYSICS IN BROWN UNIVERSITY.

Continued from Supplement No. 1697, page 22.

A STORAGE battery acts like a reservoir. It can be charged and discharged an indefinite number of times, and at rates largely at the wish of the user. Of course the device does not actually store electricity, for if such were resident in the plates or solution of which the cell is composed, analysis might reveal the essential nature of the mysterious force, but such investigations show only the original materials, somewhat changed in form, though with the same aggregate weight.

What the battery does is to experience a chemical change, and the ability of the electric current to produce such changes forms one of the most remarkable and inscrutable of all chemical and physical transformations. So wide is this field of research and commercial development as almost to make electro-chemistry constitute a separate science. The subject of storage batteries belongs in this field, but borders on that of electro-metallurgy; in the second part of this topic will be considered the use and manipulation of storage batteries, while the twenty-fourth and last of this series will describe some of the other developments of electro-chemistry.

If the idea of actual storage of electricity be sought, perhaps the spectacle of a Leyden jar comes the nearest to real existence. There is surely no chemical change produced when the electric charge is imparted to the tinfoil coatings, and certainly nothing else than a force is resident in them. That no actual electricity is present in the charged storage battery is no different conception than is presented by a copper and zinc plate in a primary battery. Whatever current is produced is entirely due to the different nature of the metals, in the presence of a solution that dissolves the one and is also in contact with the other. As soon as the chemical change is completed, though all the substance still remains, the electric current stops. The ability of a battery to store electric energy will then be readily conceived as limited to such materials as can receive a chemical change by the passage of the electric current through them, and experience no undoing of that change except upon the allowance of a current to flow in the opposite direction.

A canvass of the available materials that would comprise even a tolerable battery, to say nothing of a perfect one, will reveal the list to be surprisingly small. To be in keeping with present realizations it must be confessed that there is really only one metal and one solution that in any satisfactory manner fills the requirements. It is fortunate, too, that these materials are cheap, their preparation and manipulation involving special but no exceptional skill.

It is not to be inferred that because a suitably constructed storage cell will make good returns when new, that it will last indefinitely. All things depreciate by use, and lack of realization of the peculiar weaknesses of storage batteries led to many disastrous failures during their early days and brought considerable undeserved discredit upon their intrinsic worth. As soon as the storage principle was discovered, it was thought sufficient to adopt almost any construction, to charge the plates when desired, to let them entirely discharge, and when their use was not imperative, to let them get dry of liquid as well as of energy, to install them in some out-of-the-way place, out of sight, as well as most of the time out of mind. The present attitude is to recognize the batteries as quite as expensive as dynamo machinery and as deserving of similar care. It is certain that neglected machinery will rust and spoil, and only when reasonable attention was accorded to these chemical storehouses of electricity did they have a favorable chance to show their reliability and efficiency. A person would certainly not operate an engine without the presence of an engineer. Though the man often be merely watching, there are times when his services are imperative, and under his skilled touch long life and satisfactory operation are assured. A steam boiler is not to be operated without a pressure gage, or gage glass; the water level is not supposed to be left to the convenience of the fireman, but maintained with great watchfulness. So, with appropriate instruments and attention for the storage battery, similar desired results may be assured.

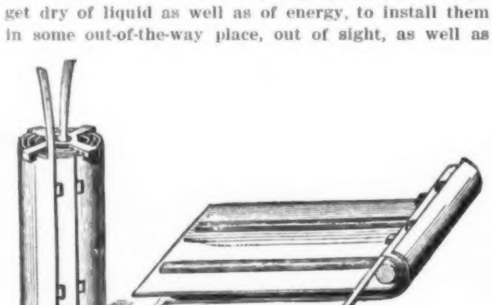

Fig. 114.—Original Form of Planté Storage Battery.

In this article sufficient directions will be given for making and using batteries of the very best types, but only those should build or buy them who realize the necessity of providing a suitable equipment of instruments, and can devote regular attention to their needs. Of course a person may build one for an experiment, but after a long season of disuse he must not be surprised if he finds the battery useless.

In 1860 Planté made the first storage cells by rolling together two long and fairly wide strips of sheet lead, separated merely by coarse canvas, and immersed in a solution of dilute sulphuric acid. After sending a current through the solution, from one plate to the other, for several hours, he found that the couple would return a current, of course in the opposite direction from that which did the charging. Since the acid soon destroyed the cloth separator, the cell was rather short-lived. In 1872 he improved the construction by using two long soft rubber strips for separators, and this material was sufficiently durable to enable the plates to be more fully "formed," and to display the unexpectedly large storage power of the element. Fig. 114 shows the method of rolling together the lead sheets as well as the coils in their finished state and ready for immersion in the solution. Rather stronger solution than the standard ten per cent mixture was found to increase the storage capacity.

Primary batteries were the only source of energy for charging the cells, and in consequence of the meagerness of these currents a long time was required to produce much chemical change in the plates. Yet by allowing many repeated charges and discharges, extending over a year or more, very respectable, though expensive, cells were made. For laboratory experiments the invention of the storage cell even in this form put a new tool into the hands of scientists, for the energy that might be storing for weeks or months could at will be expended in a short time with correspondingly great intensity, and emphasize the great power of the electric current considerably before dynamos became common. Even now it is not a bad installation for an amateur or experimenter to have a few small storage cells charged from gravity batteries. The latter can be permanently connected to the storage cells, and as long as the "blue-stone" crystals are in contact with the copper, and the zinc is in the clear solution, there need be little other care than to supply water lost by evaporation. Even this care can be minimized by pouring a layer of about a quarter of an inch of paraffin oil on the solution in both gravity and storage cells. At least three gravity cells in series will be needed to charge a single cell of the other sort, and the builder must not be discouraged if a year is required to get the plates into good working condition.

As the formation of a storage battery proceeds, it is noticed that the plate by which the current enters during the charge, and leaves during the discharge, acquires a dark color, almost black—and the material is recognized as peroxide of lead, PbO_2; although thus passing the current in both directions, this plate is commonly called the positive. The other plate normally retains the natural color of lead, but is found to become covered with a sort of scum, or lead in the spongy form. Realizing the length of time and considerable expense of producing these materials by means of the weak primary battery currents, Faure (pronounced like number four), in 1881, sought to anticipate some of this work by applying to the lead plates the well-known commercial oxides of lead that were nearest in chemical constitution to the coatings desired. He spread a layer of red lead (minium, represented by $2PbO + PbO_2$) upon the sheet intended for the positive, and litharge (PbO, having a yellow color) on the other. The two thus "pasted" were separated with a layer of felt and rolled together in much the same manner as was first used by Planté. Faure's expectations were fully realized, for he found that good working cells were obtained in much less time, and

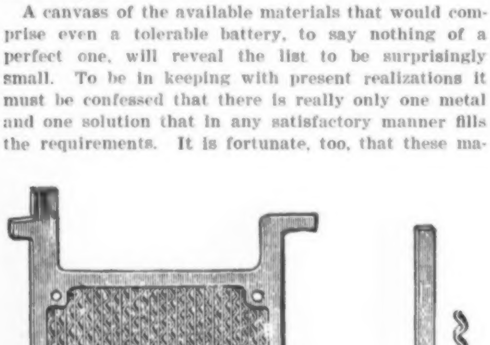

Fig. 115 – Latticed Grid for Planté or Faure Formation.

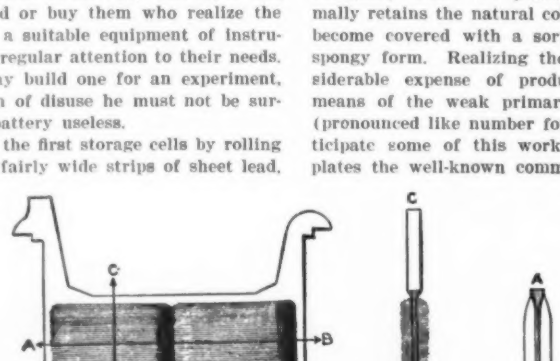

Fig. 116.—Battery Plate with Deep-rolled Grooves.

with corresponding saving in expense, than with the simpler construction. The invention was quickly patented in France, and application for a patent in this country was entered.

Brush, the "father of arc lighting," had also been experimenting with storage batteries, and had apparently just anticipated Faure. Contention in the Patent Office over the conflicting claims was so protracted that the real issue was not decided until 1886, and then in Brush's favor. In trying to develop this sort of plate, the Brush Company found certain inherent weaknesses, and did not realize the commercial success they had anticipated. Contention between infringing manufacturers left the field in an unsettled state, until a sort of trust, the Electric Storage Battery Company, was formed, to utilize all the good features of various forms of cells and processes of manufacture. Long before the expiration of the fundamental Brush patent it was found that the original Planté form of plate, in which the active materials were formed electrically out of the metallic lead, was by far superior in life and efficiency to the Faure type, and the pasted forms of positive gradually disappeared, and now some of the largest manufacturers have dropped this construction for the negatives as well.

Without attempting to describe the various and quite numerous varieties of constructions of plates, it will be sufficient to mention a few, at once the simplest and best. It is of great importance to recognize one principle, now well established, and that is to have plates and not rolls—for the better circulation of solution—and to suspend them from the top, rather than to stand on the bottom of jars. Lead is not a stiff metal, and sags under its own weight; this defect, added to the buckling or warping due to the natural expansion of the active material, renders the plates, especially those made in large sizes, less reliable than the sort which hang in a manner to keep themselves straight. In use there is also an unavoidable shedding of the active material from the surface of the plates, and in case the support is from the bottom, the accumulation of this "mud" causes noticeable short-circuiting, with consequent running down of cells. Common practice demanded the setting of the plates upon ledges raised above the general level of the bottoms of the jars, but this expedient is only moderately effective. It is just as easy and far better to hang the plates from lugs extending from the upper corners.

Fig. 115 shows a form of grid with top supports, adapted for either Planté or Faure formation. A cast frame of pure lead, about ¼ inch or 5/16 inch thick—depending upon the other dimensions of plate—is filled with strips of lead ribbon in alternately straight and crimped shape, the shape of a strip both before and after crimping being also shown. These ribbons are only about 1-32 inch thick, and come flush with the surface of the frame; the ends need to be securely attached to the frame, and by "burning" rather than by soldering. For this purpose a tiny blow-pipe flame, preferably using hydrogen gas, is the best, and after a little practice, the builder can attain considerable facility with this somewhat delicate operation. Such a flame as is now commonly employed with pyrography sets ought to be well adapted for this melting of the strips to the larger mass. If solder is used, it ought to be of specially poor quality, that is, containing as little tin as possible, and the flux should be plumber's candle or rosin—in no case the ordinary chloride of zinc solution. Four holes are shown in the corners of the frame, into which may be driven wood or hard rubber pins, projecting ¼ inch on each side, for the purpose of keeping plates apart. It is obviously sufficient to put these in one set of the plates only, preferably the negative, for that experiences the less deterioration, and the pins will remain tightly in place.

Of course the pins will not keep the plates apart if buckling or warping takes place, and so it is common practice to put in other separators, the best being of perforated hard rubber, but that material is so expensive as to lead to the substitution of thin wood slipped into slots cut in ordinary dowel-pin sticks. The wood is about the thickness used for fruit baskets, and when wet by the solution seems to offer no sensible resistance to the passage of the electrical energy. Perforations are, however, desirable to allow circulation of the acid. The objections to the use of separators of wood are based upon its gradual carbonizing, and therefore becoming somewhat of a conductor, and forming a leakage path through which the battery may slowly discharge, or by its chemical disintegration which may lead to the formation of acetic acid, the presence of which is highly detrimental to the storage qualities. Glass rods and corrugated perforated hard rubber sheets form the ideal separators.

With the plates made in the shape shown in Fig. 115, any desired number can be grouped in a single cell, always observing the rule to have one more negative than positive plate. This is necessary in order that both sides of every positive be equally acted upon, and to allow for uniform expansion as more and more of the metallic lead is converted into peroxide. If pasted plates are desired, the interstices between the strips can be filled with the proper oxides.

To do this, the plate should be laid upon a pane of glass, and the oxide mixed with dilute acid and spread over and into the plates. As these oxides (red lead for the positives and litharge for the negatives) set quickly, like plaster of Paris, only enough for one plate at a time should be mixed, and that rather thin;

Fig. 117.—Hydrometer for Measuring Specific Gravity of Battery Solution.

after waiting a moment for the setting, the plate can be completely slid from the glass, and the other side similarly treated. After the pasting process the plates should be allowed to dry for a day, then once daily plunged into dilute acid, until all sizzling or heating disappears. Unless this precaution is taken, the assemblage of the plates in the regular acid will result in such an evolution of hydrogen gas as to dislocate and even expel some of the filling.

Each set of plates is connected together by means

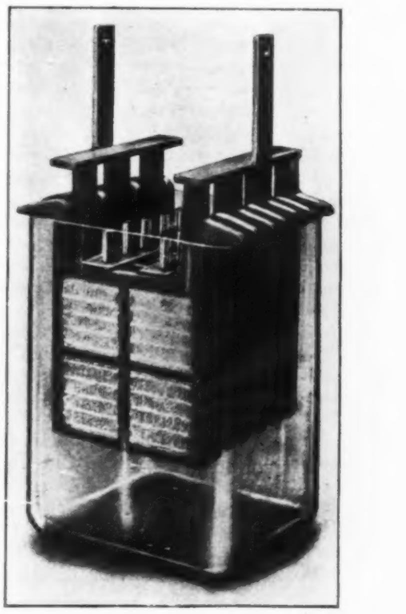

Fig. 118.—Small Size of Battery Assembled in Glass Jar.

of the lugs at the top being soldered to cross-bars. A separation between like plates can well be ⅞ inch to 1 inch. It is a mistake to crowd them closer. Neither should the edges of plates come nearer than ½ inch from the sides of jars. Even greater space is desirable. Space must be provided for the insertion of the hydrometer for measuring the specific gravity of the solution, and also for allowance for the natural growth of the positive plates.

resulting shape, along with the uncut stiffening ribs.

An amateur can make similarly effective plates from rolled or cast lead slabs, by cutting the grooves entirely across by use of an appropriate tool in a planer or shaper. The proper shape of tool can be judged by considering how a sheet of paper would best be cut by drawing a knife over it. The blade would not be held perpendicularly, nor poked under like a hook, but given a considerable slant; if now, in addition to this slant, the blade be tipped sidewise, at an angle of 30 or 45 deg., the shape of the cutting edge of the planer tool is given. Like the farmer's plow, the tool is to cut into the metal and turn it over like a furrow, but not to remove the stock. From fourteen to sixteen cuts per inch should be allowed, and if the slab is ¼ inch or 5/16 inch thick to start with, the final thickness, allowing for an uncut backing of ⅛ inch, will be nearly ½ inch.

Chemically pure materials must be used, else the impurities present will allow the formation of other compounds than those intended, and the battery will fail to hold its charge, and return the expected energy. Lead of the desilverized quality should be sought, and this costs only about one-half cent more per pound than the ordinary commercial pig lead. Sulphuric acid is readily obtainable from the manufacturers in the proper dilution, and unless the distance is so great as to render the transportation of the dilute acid too great, this is better than purchasing the concentrated grade and then diluting it on the spot. The builder does not ordinarily have vessels large enough to mix the whole quantity at once, yet all the cells need filling at closely the same time. Distributing the solution in many small vessels leads to inevitable differences of density. At the works the concentrated acid receives its final treatment in stills made of platinum, and conducted in gold pipes. Although it is a common statement that these metals are unaffected by the acid, it is a matter of serious knowledge to the owners that the stills and pipes gradually disappear. It is found that of all foreign metals in a storage battery, the least trace of platinum will work the most harm, and gold comes next. Therefore if the dilute acid is purchased, direct from the works of course, the sort that has received only a moderate degree of concentration in leaden vessels, the chances are favorable for securing a pure quality at moderate cost.

The proper strength of solution to be used is that having a specific gravity of 1.21, water being 1; it will be explained a little later that in the normal operation o the battery this density changes, and this variation serves as one of the surest indications as to the condition of charge or discharge. It is well, however, to purchase acid a little stronger than this, for as soon as the plates are immersed, some lead is changed to lead sulphate, or some of the oxides suffer further decomposition, and this means the using up of some acid. To forestall the necessity of then adding strong acid, that of density of about 1.25 or 1.26 may well be purchased in the first place. The builder who tries to do any serious work with a storage battery must not think of ignoring the use of the hydrometer. A steam engineer could as well dispense with a water gage on his boiler. If Baumé's graduations of hydrometer be used, the mark of about 24.5 is to be followed, or if the kind at hand is marked 1,150 to 1,250 a decimal point is to be imagined after the first figure, and then the instrument becomes direct reading.

Hydrometers are weighted with either mercury or fine lead shot. Since the breakage of the tube will spill the contents into the cell, it is seen that the latter sort is preferable, mercury being highly detrimental to the life of the plates. A mercury-weighted hydrometer is shown in Fig. 117.

Since the Planté method of formation is now commonly practised, it is usual for manufacturers to use

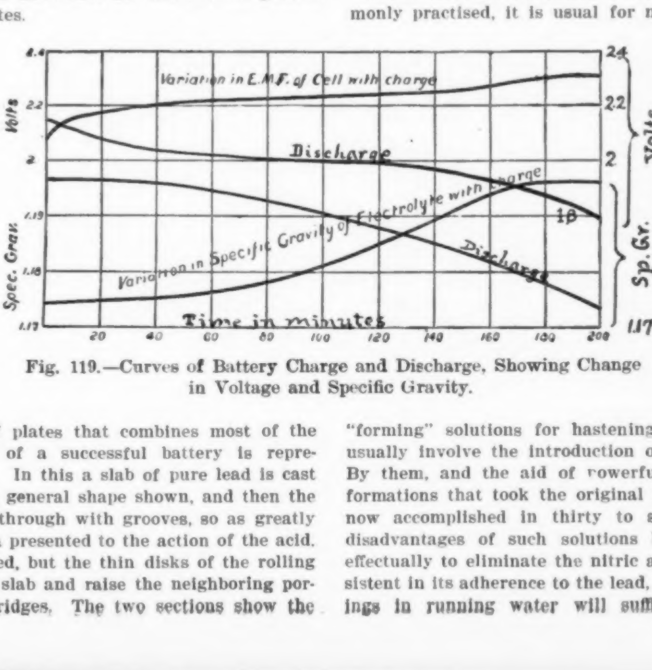

Fig. 119.—Curves of Battery Charge and Discharge, Showing Change in Voltage and Specific Gravity.

Another form of plates that combines most of the desirable features of a successful battery is represented in Fig. 116. In this a slab of pure lead is cast or pressed into the general shape shown, and then the surface nearly cut through with grooves, so as greatly to increase the area presented to the action of the acid. No metal is removed, but the thin disks of the rolling tool press into the slab and raise the neighboring portions into fins or ridges. The two sections show the

"forming" solutions for hastening the process; such usually involve the introduction of dilute nitric acid. By them, and the aid of powerful dynamo currents, formations that took the original inventor a year are now accomplished in thirty to seventy hours. The disadvantages of such solutions lie in the inability effectually to eliminate the nitric acid. It is very persistent in its adherence to the lead, and only long washings in running water will suffice to eradicate it.

Chlorides, too, are difficult to eliminate, and the particular process involved in the "chloride" plates is now completely abandoned—the name being retained merely as a trade-mark.

After assembling the plates of a battery, they must not be placed in the solution until the charging current is all ready. Batteries suffer more from inaction than use, and especially must the plates not be left in the discharged condition. Whether home-made or purchased, the plates when assembled are in the discharged condition, and inattention to the proper initial conditions may give the plates a setback almost impossible to overcome. Continuous charging for twenty-four hours is imperative, and the manufacturers usually demand double that, or until the voltage and specific gravity have reached certain high and definite limits. After thus putting the cells into proper good initial condition, no such overcharging is needed, except at long intervals. Still, in places where reliability of operation is of prime importance, as in telephone exchanges, it is not uncommon practice to overcharge the cells once a week.

The chemistry of storage battery operation consists in the fact that upon the first immersion of the plates in the sulphuric acid solution, some metallic lead on both plates is acted upon, whereby lead sulphate is formed and hydrogen gas liberated. After this exceedingly thin skin of sulphate has formed, no further action takes place until a charging current of electricity is sent through. Even in this case, metallic lead is not transferred to the negative plate, as would be the case in a plating cell, for the fundamental reason that the solution is not a salt of the metal of which the anode is composed. If lead were to be electrically deposited, a solution involving lead acetate or potassium plumbate would be needed. Since the solution, however, contains no lead, this metal being practically insoluble in sulphuric acid, the passage of the current merely decomposes the solution. Authorities somewhat disagree as to some of the intermediate transpositions of the molecules or atoms, but the final products are plain. The acid is decomposed or disassociated, the hydrogen passing with the current to the negative plate, while the remainder of the molecule—the sulphuric oxide—goes against the current to the positive plate. Here the latter "ion," being rich in oxygen, unites with lead sulphate and water to form lead peroxide and two molecules of acid. Also, the hydrogen that reached the negative plate displaces the lead in the lead sulphate, deposits it in the spongy form, and produces another molecule of acid. Thus it is seen that in the charge, for every molecule of acid decomposed, three have been formed. Confirmation of this gain in ac . is conclusive from the indications of the hydrometer, and the progress and amount of the charge is faithfully testified by this simple instrument. As the charging proceeds, the voltage somewhat rises, though on an ordinary voltmeter the readings are not so conclusive as those of the float. During the discharge the opposite steps could be traced, with the result of showing that sulphuric acid was used up, the specific gravity of the solution consequently falling.

In Fig. 119 is given a set of curves depicting the performance of a small cell during periods of charge and discharge extending over about three hours. At the beginning of the charge the voltage of cell was nearly 2.1 volts, and for a long interval was not far from 2.2 volts, but finally reached 2.3. The specific gravity, however, went from somewhat less than 1.176 to 1.196, a very readable difference on a hydrometer. After a short wait, the disengagement of the excess hydrogen gases had allowed the voltage to fall to the value of 2.15, from which, during the discharge, the pressure gradually approached the 2-volt line, holding that for a considerable time, but at length reaching the minimum safe limit of 1.8, at which point the discharge was properly stopped. As seen from the diagram, the lowering of the specific gravity of the solution was constant and unmistakable.

To the person, then, who would regard the storage battery, not as a haphazard arrangement to be toyed with at will, but as a scientific implement of complex chemical and physical structure, it will give a wonderful stimulus of thought and respect. The device cannot be called perfect, but this estimate must not be based on the mere factor of great weight, for many mechanical devices are admittedly heavy, and yet highly satisfactory. On the score of efficiency the storage cell can readily return seventy-five per cent of the energy put in, so in this respect it stands in the foreground with steam engines and waterwheels. The real shortcomings of the batteries have been exposed through the somewhat improper uses to which they have been put. The positive plates are little else than lead ashes, and ashes in any form are not accredited with much mechanical strength. Therefore for portable use, on automobiles and railway cars, the short life experienced is quite explainable. In central stations and for other stationary uses, when as skilled attention has been accorded to them as to the machinery, they have filled all reasonable expectations.

It is true that this sort of battery has its frailties, and some of these are of peculiarly insidious character. Chief among them may be emphasized the possibility of the plates—particularly the negative—acquiring an excess of lead sulphate, more than is regularly changed by the current to the peroxide or into spongy lead. This sulphate readily forms when the battery is left in a discharged condition, or when the solution is too weak. Being essentially a non-conductor of electricity, whatever portions of the plate are covered are thereby prevented from receiving their normal charge, the remaining parts are charged or discharged more than expected, with consequent warping and other kindred troubles. Without entering into details, it is sufficient to affirm that most of the failures of storage batteries in the hands of inexperienced attendants can be attributed to this "sulphating."

Until lately the positive plates of a battery have been looked upon as the weaker, and subject to the greater solicitude. Experience has led to the construction of very satisfactory plates for this polarity, and now it is found that the negative has its own causes of depreciation. The evidence has been manifested in the gradual diminution of storage capacity of the cells, even with new positives. Examination shows the ultimate reason to be that the negative plate, instead of retaining the lead in the spongy condition, with great area exposed for chemical action, becomes somewhat reduced to the condition of solid metallic lead. Remedies for this lapse are now being sought, and by some inventors claimed to have been found.

Direct sunlight seems to have some injurious effect upon the batteries, the real nature being rather obscure. While there is importance in having the cells in a sufficiently light place to be regularly seen and cared for, some caution must be observed not to put them in a place too light and hot. For experimenters and owners of small installations, the use of a layer of paraffin oil on the cells is to be recommended. Evaporation of the water and spraying of the acid will be largely suppressed, but it might be well for the experimenter to try it on one cell, and see how he regards it. The use of the hydrometer is interfered with, for to use it, a sample of the liquid must be withdrawn with a pipette, and run into a test tube. As a matter of fact, for laboratory purposes, or for other irregular uses, daily hydrometer readings are not necessary, and the use of oil is quite allowable. While accumulation of dust and oil makes a rather nasty combination, and one not particularly inviting in case of overhauling, the oil is really something of a protection for the hands, for with a coating of that unguent, the attacks of the acid are mollified.

At the outset of this article it was stated that only one metal and one solution have yet been found for producing a good storage cell. The reader has seen what these two are. Other materials have been zealously sought, but in every case some insurmountable defects have been found. There is not space here to explain the various attempts at lead-zinc and nickel-iron couples, for if so, a false estimate of their commercial value might be given. Nor is it to be expected that any new metals will be discovered of greater promise in electrical storage properties than those now at hand.

In the next chapter will be given some explanation of the switchboard arrangements and methods of practical operation of the batteries.

SALT MAKING BY FUSION.

At the present time great interest has been aroused in Great Britain by a new fusion process for manufacturing salt that has been evolved by Mr. Robert Tee. The commercial perfection of such a system opens great possibilities, since the evaporation process now in vogue, and which has obtained since the Roman occupation, is both slow and costly, a ton of salt of the commonest grade consuming in its production about half a ton of coal, while for the finest qualities three-quarters of a ton of coal are necessary to produce one ton of salt.

Owing to this high consumption of fuel, several efforts have been made from time to time to evolve a cheaper and quicker process of purifying the crude product as obtained from the mines. The fusion process has been regarded as the most favorable solution of the problem, but unfortunately, however, the perfection of such a method involves the surmounting of several difficulties. Briefly, the process consists of melting the salt, and when in its molten condition removing the organic impurities associated with the raw material, which is no easy task. The rock salt as it is brought from the mine is totally unfit for use. It is dirty and considerably discolored, ranging from dark red and brown to a light yellow, the latter being considered as that containing the least proportion of impurities.

In carrying out any fusion process, however, the significant point has to be borne in mind, that although salt melts at 1,400 deg. F., this temperature also constitutes its volatilization point, and this very fact constitutes the prime obstacle that has to be overcome in carrying out any purifying process by fusion. It is obvious that although a sufficient temperature must be utilized to bring about the rapid conversion of the mineral to a molten condition, volatilization to any high degree must be avoided, otherwise success will be limited, since the yield of white salt per ton of fuel will not be sufficient to render the system commercially practicable in comparison with the simpler evaporation system. Moreover, it must be taken into consideration that salt in itself is a very bad conductor of heat. This necessitates the employment of shallow vessels to carry out melting operations, since otherwise while the salt at the bottom of the crucible is quite hard and solid, that at the surface will be molten and volatilizing.

Successive inventors have perfected a variety of apparatus and methods for securing the desired end, but only moderate success has been attained. One or two of the systems have demonstrated great possibilities, but the plant required for the purpose has been of such a complicated and expensive nature as to render it commercially impracticable. Even when the questions of melting and volatilization have been overcome, the task of bleaching the product has proved insuperable, so that the salt obtained while having a fair degree of purity has possessed such an uninviting appearance as to be quite useless for table purposes.

Recently, however, as demonstrations have shown, Mr. Tee has overcome both these difficulties by his system. The rock salt as it is received from the mine is delivered into a special furnace, where it is quickly melted. In its molten condition it is an opaque and dirty-looking mass, and in this condition is drawn off into a receiver or ladle, where it is subjected to a treatment similar to that adopted in the Bessemer process of manufacturing steel. Compressed air is forced through the liquid mass, which violently agitates it, and the impurities are either blown through the top of the converter, or caused to precipitate at the bottom of the vessel. A few minutes is sufficient to complete this operation, at the conclusion of which the molten mass upon settlement becomes almost transparent liquid, all the foreign substances previously suspended in the product having disappeared or settled at the bottom of the ladle.

Purification completed, the molten mass can if desired be run off into molds of various shapes and sizes as required, or if preferred it can be allowed to solidify in the ladle. In the latter event it is subsequently removed in a solid mass with the impurities, forming a thick incrustation at the base of the mold. Even this waste product is of commercial value, since it possesses valuable fertilizing qualities, and consequently can be sold as manure.

If poured into the molds, the salt can, upon solidification, be sold in the rock form, and being of an intense white it has an attractive appearance. If permitted to cool in the converter or ladle and subsequently removed in broken masses, it is subjected to pulverization and graded by screening, the finest powder being suitable for table use and the coarser product for ordinary manufacturing processes, such as curing and so forth.

The great advantage of the Tee process is that the removal of the organic impurities and bleaching are carried out in one operation, while at the same time any grade of salt can be secured merely by suitable screening. As compared with the evaporation process, this is a distinct improvement, since in the latter system the various qualities of salt are secured by evaporating the brine at varying and special temperatures. The commercial possibilities of the new fusion process may be realized from the fact that whereas by evaporation from 10 to 15 hundredweight of fuel is required to produce one ton of salt, by fusion the same quantity of salt can be secured by the consumption of about 170 pounds of coal. Practical experiment has shown that on the basis of $3.75 per ton of salt, which is the average market price of the commodity, one ton of coal will suffice for the manufacture of 15 tons of finished salt worth $56.25, as compared with two tons of salt worth $7.50 by evaporation.

The fusion-manufactured salt is stated to possess further recommendatory features which should appeal to the general public. When powdered it is not liable to cake in keeping, and does not readily absorb atmospheric moisture. For table purposes therefore it should prove especially suitable, since at the present time such a condiment has to be subjected to further processes and combined with certain foreign substances, such as corn flour, in order to preserve its finely divided condition.

R. William Thom, of Southport, England, recommends the employment of internal combustion engines fed with coal gas carried in cylinders, under compression, in the barge, for propulsion of canal barges. He claims that the system possesses many advantages over gasoline or steam engines, and says that the engines and storage cylinders would only weigh half as much as steam engines of corresponding power. The space occupied is also much less. Tests made in England are said to bear out his claims.

THE PROBLEM OF ROAD CONSTRUCTION.*

A CONSIDERATION OF MODERN AND FUTURE REQUIREMENTS

BY DR. H. S. HELE-SHAW, F.R.S., AND DOUGLAS MACKENZIE.

QUITE apart from the mechanical features of road locomotion, involving a necessity of reform in road construction, there is the underlying cause of the increase in the use of roads to-day, the cause in question being the growth, at present, of railway traffic.

While the railways are truly the arteries and veins of the nation, and have as such received great attention, very much less consideration has been given to the ordinary roads, which might be considered as the capillaries or feeders, and which are just as vital to the satisfactory working of the system of internal transportation as a whole.

The object of the present paper is to consider the problem of road construction, and particularly as to how far the various improvements in the methods of road-making which have been devised and put into operation since the passing of the Light Locomotives Act of 1896 satisfy modern requirements. Also what progress the various new systems of road construction have made toward standardization of modern road-making comparable with that arrived at by the pioneers, Telford, Macadam, and others in their day, for the traffic conditions of the time.

As long as the speed of vehicles was slow, the axle-load moderate, and the tractive effort was not derived from the wheel itself, the surface of a road, even when carrying a considerable amount of traffic, could be kept in fairly good condition by means of a moderate annual expenditure, even when the surface was not very hard, nor the substance of it impervious to moisture.

Under the changed conditions of to-day, however, the increased expenditure has been so great as justly to alarm the authorities throughout the country responsible for the use of the roads.

Mr. Howard Humphreys, in a paper read recently before the Society of Road Traction Engineers, gave some valuable data on the subject. Some of these facts are worth summarizing. Thus the increase of cost in main roads in thirteen years, from 1892 to 1905, had increased 66.66 per cent. The urban and rural roads between the twelve months ending March 31, 1896, showed the cost of 25,650 miles of main road to be $332 per mile; last year the cost of 27,380 miles of main road was $440 per mile, being an increase of 30.51 per cent. These data all tell the same tale, and that tale is one which can only be heard with the gravest concern, since from it two things are quite evident.

(1) That the rate-paying possibilities in country districts will not be equal to a much further rise in expenditure, even if they can continue to meet the charge what it has risen to at present.

(2) That so far from having reached a state of finality in regard to motor traffic, the increase in expenditure is merely due (or to a large extent due) to what might be called light motor traffic. Heavy motor traffic is yet in a comparatively undeveloped state, with possible increase before it far exceeding that of the future of light traffic.

It is not to be wondered at that public attention is being attracted to a matter which touches everyone so vitally, though it is probable that the dust nuisance—as it is very properly called—has really had more to do with the public interest in the road question than the matter of the increased cost of their upkeep, though, as will be shown, the efficient road must really be, as a natural concomitant, a dustless one.

Proposals have recently been made for the nationalization of the roads, and for the taxation of motor vehicles for road improvement and maintenance. With these questions the present paper does not deal, but rather with the equally important one as to what is the best way of dealing with road construction from the engineering point of view, so as to secure the most efficient road at the lowest cost.

There is only one really sound way of approaching the problem of construction, and that is to regard the road as one element of a mechanical contrivance, of which the wheel is the other element. This aspect of the matter seems too often to be entirely overlooked. Inventors of a wheel and the makers of a road, respectively, too often treat their part of the problem without reference to the other part, whereas these parts are only two halves of a whole.

More than thirty years ago there was translated from the German, by Prof. (now Sir Alexander) Kennedy, the "Kinematics of Machinery," of Prof. Reuleaux, and in that work for the first time the true conception of a machine was set forth. We now realize that the action of a rope on a pulley, water in a hydraulic system, or a wheel on a road, might be considered as much cases of mechanical action as that of the two tooth wheels working in contact with each other. It was truly said in the above work: "A machine may be perfect, or may contain more or fewer imperfections: it approaches perfection just in proportion as it corresponds to what we have recognized as its special object—the special end for which it has been constructed."

Now the special end for which two elements in the case of a pair (a higher pair as it is called in the case of rolling contact), viz., the wheel and the road, are designed is that they may run smoothly and in contact with each other, resisting considerable mutual pressures without permanent deformation and without undue wear or loss of energy. The ideal condition of things is obviously that in which a perfectly hard and perfectly circular wheel runs on a perfectly hard and level road. It might be said, therefore, that a steel wheel and a steel road would be suitable as in the case of railway practice. As a matter of fact, quite apart from the practical question of the cost of such a road, there are questions of adhesion, in the matter of gradients as well as steering, that make a metal road quite out of the question. Assuming, then, that a really hard road cannot be obtained, it may be at once said that if a moderately hard road could be kept level and entirely free from all unevenness of surface there could be nothing better than a truly circular metal wheel, and such a wheel being cheap and durable would doubtless be universally employed.

But a thing so desirable as a truly level surface is exactly what it is impossible to maintain, and it is in order to mitigate the shocks caused by the tendency to deflect a vehicle from its movement in the straight course that yielding material such as solid rubber or pneumatic tires are employed on the periphery of a wheel. Now we cannot employ this soft material without paying the penalty, not merely of wearing the wheel, but of wearing the road itself, and as a matter of fact insomuch as the contact between the wheel and the road departs from a point in the side elevation, or a line looked at in plan, by so much is wear between the surfaces in contact introduced. In the next place let us consider what goes on beneath the surface. If the road is not hard, then a certain amount of deformation must take place.

The injury done by this deformation will depend on two things:

(1) The depth to which it will extend (i. e., magnitude of deformation).

(2) The extent of permanent disintegration of the internal substance of the road.

It is obvious from the foregoing remarks that, both as far as the surface is concerned and also the body of the road, what is required is a tough elastic material, or if on the score of expense it is impossible to have such a material for the whole of the road, then the material of which the road is actually composed should be cemented or bound together by such a material.

In any case, as the road is exposed to the action of the weather, one of the very first conditions of its efficiency is that it must be waterproof, and that the surface must be sufficiently hard to prevent as much as possible the formation of liquid material—let us call it mud—in wet weather, and loose, finely-divided particles—let us say dust—in dry weather.

Quite apart from the question of irregularities on the surface, which will not be considered, the difference between the perfect rolling of a hard wheel on a smooth surface, in the case where either the wheel or the road, or both, are soft, demands attention in the study of road construction.

Restrictions have very properly been devised and are enforced by law with a view of protecting the roads from undue destruction by wheels; but it is clear that just as there are demands made for road improvement on the one hand, so will demands be made and vigorously voiced for further restrictions in the matter of wheels on the other. The use of studded tires is a case in point, and the authors think that, concerning its use, road surveyors have a just grievance at the present time. The new studded tire with projecting steel studs and rotated by an engine of 40 to 60 H. P. is capable, in passing along the road, especially in climbing hills at a high rate of speed, of doing a considerable amount of damage to the surface of a road, and when scores, if not hundreds, of such tires pass along one piece of road in a day, it is obvious that there is no road surface, unless made of steel itself, that would not be cut to pieces in a short time by such means.

With regard to the types of heavy commercial vehicles, it is certain that unless the diameter of their wheels is increased, they will form, as this class of traffic increases in future, a very serious problem to the road constructor. It is astonishing how much the injury to a road surface is reduced by the comparatively small increase in the size of wheels of steam tractors, which average about 4 feet 6 inches in diameter, as against 3 feet 6 inches of a heavy motor vehicle. Of course, even better comparative results are obtained with the much larger wheels of the heavy traction engine, and the authors do not think it is going too far to say that if the wheels of such traction engines were not of the size they are, the passage of one such traction engine on a road, in certain states of the weather, drawing, of course, its full load, would be sufficient to do incalculable damage; that is, assuming it were able to pull its load at all. The authors do not wish to enter further into the question of the wheel. They have drawn attention to some of the chief points which are of pressing importance in the matter of road construction, and wish, in conclusion, to remark that, while they have shown that there must be sympathetic co-operation between the designer of the wheels of a motor vehicle and the surveyor who is responsible for the maintenance of the road, there is a third party who has a serious responsibility in the matter—namely, the user of the road.

However good the road, and however well designed are the wheels, a great responsibility must rest with the driver of a motor vehicle. By the incessant use of the crown of the road, leading to tracking, by the injudicious use of brakes, by the rushing of corners at unreasonable speeds, and in many other ways, the driver of a motor vehicle can do more damage in a week to the roads, as well as to the vehicle he is responsible for, than would otherwise be the result of twelve months' fair usage. The authors trust they have shown that if the drivers and manufacturers do their part the science of road construction has now advanced sufficiently for the road surveyor to be able to do his part without putting an undue and even prohibitive burden upon the community.

* From a paper recently read before the Royal Society of Arts.

A NEW METALLIC MIRROR FOR SEARCHLIGHTS.

EVER since the introduction of searchlights for naval use efforts have been made to substitute metallic mirrors for those of glass. The latter are unsatisfactory because they are readily broken by concussion when firing the guns, and the silvering is liable to blister and leave the surface of the glass. However, the difficulty of making true parabolic metallic mirrors has been completely overcome by means of the Cowper-Coles electrolytic process. Briefly, this consists of depositing by chemical means on the convex face of a glass former, or mold, a thin silver film and then spinning the former in an electrolytic cell charged with copper nodules and a copper electrolyte, so as to deposit the copper on the silver surface, the process being continued until the silver film has received a sufficient backing of copper to give it the desired rigidity. The glass mold and the electro-deposit are then removed from the depositing cell and placed in a vessel containing cold water, the temperature of which is gradually raised until the expansion of the copper is sufficient to cause the metal to leave the glass former. The silver-faced mirror thus produced has as highly polished a surface as glass, and is finally subjected to an after treatment to prevent it from tarnishing. It is then mounted on a metallic ring which fits in the projector case provided with knife edges which firmly grip the edge of the mirror without distorting it. A large number of mirrors made by this process have been acquired by the British government, the working and durability of which have proved eminently successful.

The inventor, however, is now introducing a new metallic mirror which is only partially made by electro-deposition. The mirror has a surface composed of alternate bands or rings of gold and white reflecting surfaces which it is claimed give a more penetrating beam of light both at night and in foggy weather. Objects on which such a ray of light is thrown stand out in greater relief than in a light projected from a silver-white metal mirror and the intensity of the light is so great that it is impossible to aim accurately at the projector.

Another great advantage of the new type of mirror is that it is not fractured by concussion and even when penetrated by bullets the area of distortion is small.

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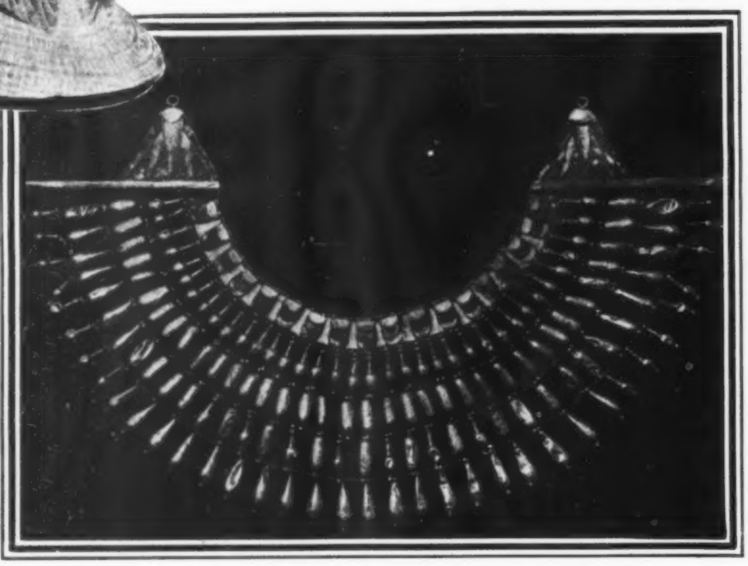

THE GOLDEN NECKLACE WITH LILY-SHAPED CLASPS

TWO PORTRAIT HEADS OF QUEE M THE CAN

THE EXTERIOR OF THE TOMB, WITH AN EGYPTIAN POLICEMAN GUARDING THE ENTRANCE

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UNVEILED AFTER 3,300 YEARS: THE BURIAL PLACE OF QUEEN THI COFFIN,

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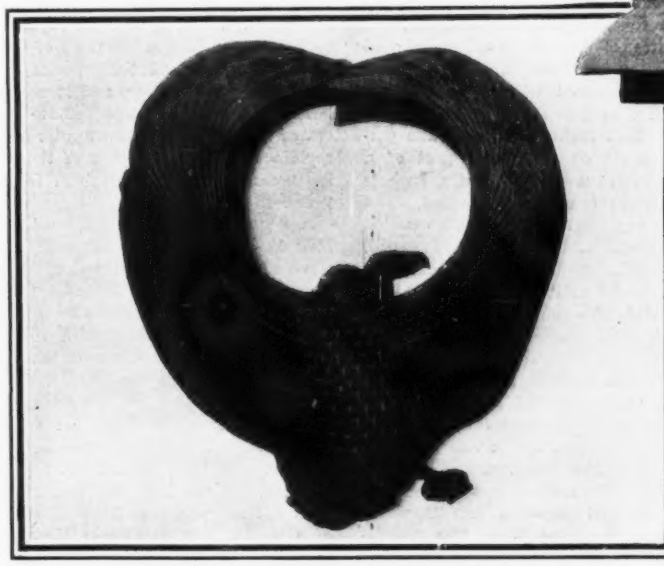
QUEEN M THE CANOPIC JARS OF ALABASTER



THE ROYAL VULTURE DIADEM OF GOLD

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THE INTERIOR OF THE TOMB, WITH THE MUMMY COFFIN SURROUNDED BY SHEETS OF GOLD

THI OFFIN, AND SOME OF THE TREASURES FOUND WITH IT.—[SEE NEXT PAGE.]

TWO NOTABLE EGYPTIAN TOMBS.

DISCOVERIES OF HISTORIC AND ARCHÆOLOGICAL INTEREST, MADE BY AMERICAN EXCAVATORS.

During the past two years two finds of more than usual interest have been made by archæologists in Egypt. Early in the year excavators in the Valley of the Tombs of the Kings at Thebes, working under the direction of Mr. Theodore M. Davis, of Newport, uncovered the entrance to what was evidently a royal burial place. The entrance was cut in a hillside, and from it a rough stairway led down into the hill, terminating in a passage, blocked with a wall, which when removed, showed a steep incline leading in a few yards to a chamber. This inclined passage was partially blocked with stones on which lay part of a sarcophagus, of cedar wood coated with gold, the whole dry, rotten and ready to crumble if touched. Not without difficulty the explorers of the tomb crawled over the block without disturbing the decayed wood, and stood in the funeral chamber. In one corner of the chamber was a splendid coffin, of the usual Egyptian form, lavishly inlaid with rare stones and colored glass. By the electric light which the explorers carried, it was seen that the bier supporting the coffin had given way and that in the fall the coffin lid had slipped partly off, disclosing the skull, encircled with a gold crown. In a recess in the wall stood four alabaster canopic jars—jars for holding the viscera of the deceased—each with a lid exquisitely sculptured in the form of a feminine head. In a corner was a box containing little toilet vases and porcelain utensils, while other objects were lying about the floor. The inscription on the coffin bore the name of Akhnaton, Pharaoh of Egypt, but other inscriptions in the shrine said that the Pharaoh had made the tomb for his mother, Queen Thiy. The tomb was certainly made for the queen and the toilet utensils bore her name; the heads forming the lids of the canopic jars were undoubtedly feminine; and finally a passing doctor examined some of the bones of the much decayed mummy and pronounced them those of a woman.

Queen Thiy has long been an object of interest to Egyptologists, and the circumstantial announcement of the discovery of her body aroused much interest. Some weeks afterward some of the bones, soaked in wax to prevent their breaking, were sent to Dr. Elliott Smith, an eminent osteologist. He wrote to the sender: "Instead of the bones of an old woman, you have sent me those of a young man; surely, there is some mistake." There was no mistake, however; the bones were declared to be those of a young man of about twenty-five, powerfully built. This description scarcely coincided with the theory formed of Akhnaton's physique and age at death, but it now seems certain that they are the bones of Queen Thiy's great son, and that the theories were wrong.

Akhnaton is one of the most interesting figures in Egyptian history. His life—for he lived a life in spite of his early death—was one of high ideals, doomed to failure. His mother—Queen Thiy—was a Syrian princess, with the speculative religious beliefs of the East, and when her son was born, after twenty years of married life, she must have imbued him with her own advanced ideas, rendered militant in her, perhaps, by the ultra-conservatism of the Egyptian priesthood. When Akhnaton was eight years old his mother assumed the regency, and for six years held the reins, until her husband, after a long incapacitating sickness, died.

At the age of fourteen the new Pharaoh, who was already married, took full control, and at once began a bitter opposition to the priests. Deserting Thebes, where the priests were intrenched in the conventions of centuries, he founded a new city half way between Thebes and Cairo on the site where the village of El Amarna now stands. Here the hills curve back from the river, making a bay about five miles long and three deep. A capital of magnificent temples and palaces was erected, and boundary stones were raised on which the young king inscribed an oath that he would never leave his beloved bay city—an oath which he appears to have kept. Here he instituted his new religion; an enlightened recognition of "the heat which is in the sun," really an ethical teaching repudiating the old gods of mythology, and leaning toward peace and brotherhood. The king was surrounded by his chosen priests and nobles, probably flatterers and time-servers; and with all his thoughts bent on a peaceful religion, lent slight heed to grave temporal affairs of state. Egypt held wide territory in those days, extending southward to the Sudan, and in the northeast reaching through Palestine to Asia Minor and the Euphrates. While the king dabbled in religion, wild tribes were hammering at his outposts. For years piteous appeals from frontier towns had been ignored; and suddenly word came that the great Egyptian empire, which the king had hoped to bind in a religion of peace and truth, was an empire no more. The Asiatic princes had thrown off the yoke and proclaimed their independence. It was a sudden awakening for the king, and a fatal one; he sank under the blow and died.

On Akhnaton's death the town in the curve of the Nile was abandoned, and the royal corpse was carried to Thebes and laid in the tomb of Queen Thiy. But as the priests regained their power, the late king was denounced as a heretic, and it would appear that the body of his mother was removed to some "undesecrated" spot, where it now awaits discovery. The king remained the sole occupant of the shrine he built for his mother, and has remained there for about 3,300 years.

A second excavating party, working on behalf of the New York Metropolitan Museum of Art, has been at work on a concession granted to them by the Egyptian government. The site includes the two pyramids of Lisht, about thirty-five miles south of Cairo, and a strip of land stretching northward for about nine miles, containing a number of cemeteries. In one of the cemeteries, dating from the twelfth dynasty (about 2000—1750 B.C.) about one hundred tombs have been opened. In most of these the twentieth century explorers have found themselves forestalled by ancient diggers, who have opened the tombs for the sake of plunder; but one tomb was found which though it had been entered was practically intact. This tomb—that of a lady named Senbtes—yielded interesting archæological knowledge, and we give a description of it, abstracted from the account of Mr. Mace, one of the men who cleared the tomb—a task on which two men were engaged for more than two months. The tomb consisted of a vertical shaft 26 feet deep, opening at the bottom into a large offering chamber about 5 feet high, and within this a long narrow chamber containing the body. Like other graves, this one had evidently been opened, but the only damage done was the stripping of the gold leaf from the outer coffin. Presumably the despoilers were disturbed before they could complete their task. The outer chamber contained only pottery; one hundred and eight pieces, mostly tiny model vases and saucers. In the inner chamber, which points north, the coffin lay close to the west wall. The canopy niche was as usual built into the east wall of the chamber, the vases being held in a gilded and decorated box of wood. The vases were of alabaster with painted wooden heads. The body was inclosed in three coffins, the outer one much decayed. The second coffin was of hard wood, probably cedar, the wood in good condition. The lid was decorated with bands of gold leaf, on one of which was an incised inscription giving the names of the person for whom the tomb was constructed. This gold leaf had not been glued directly to the coffin, a thin layer of plaster being interposed Consequently, much of it was hanging loose, and it had to be carefully restuck, inch by inch, before the lid could be raised.

Inside this coffin were a number of folded shawls covering the innermost coffin; among the shawls were a number of ceremonial staves and one whip. This latter belongs to a type which is well known in the twelfth dynasty, but has very rarely been found in perfect condition. The handle and flail ends are of wood; the long cylindrical beads are of blue pottery ringed with gold at the ends, and the smaller beads are of carnelian and blue-glazed pottery, also with gold rings.

The innermost coffin was as usual of human form and of elaborate design. It was on opening this that the interesting discovery was made, for the body, which was well preserved, showed clear traces of mummification. It has been supposed that embalming of the body was practised as early as the twelfth dynasty, but it is unusual to find more than the bare skeleton; and until this discovery there has been no definitely recorded case of pre-eighteenth century mummification.

Dr. Elliott Smith, who examined the body, says that the Lady Senbtes was a very small and exceedingly slenderly built woman of about fifty years of age. The face is very small and infantile, the eyes large and round, the nose well-proportioned, being neither aquiline nor flat. The teeth were small and regular and remarkably little worn.

The dainty little lady was buried with her finery. The body, after embalming and placing in the coffin, was covered with a layer of pitch, and this pitch settled to one side, dragging with it the ornaments which appear to have been placed on the body outside the final wrappings. These ornaments included a circlet from the head, formed of three coils of twisted gold wire, and a series of ninety-eight tiny gold rosettes which were dotted over the hair; a necklace of tin beads—gold, beryl, and carnelian—with gold shell pendants; bracelets, a girdle, a number of armlets and other small decorations. Inclosed in the wrappings were a number of other feminine possessions in bead work of ivory, carnelian, gold, and other material.

After nearly four thousand years beneath the soil of Egypt these relics have been brought to New York and placed in the Metropolitan Museum of Art.

SIMULTANEOUS MINE EXPLOSIONS IN DIFFERENT COUNTRIES.

In the French technical paper Echo des Mines et de la Métallurgie, the well-known author Francis Laur writes as follows on this interesting subject:

The simultaneous explosions of gas in the Reden mine in Germany, the Lievin in France, and the Charlestown in England, had a common cause, which the most obstinate opponent of the theory of the influence of seismatic and atmospheric phenomena must admit to be explained as follows:

From 1877 on, the author has shown that earthquakes and low barometric pressure have an influence on the flow of explosive gases in mines. He does not claim that every reduction of barometric pressure causes such flow of gas, but such reduction is necessary to a catastrophe, where, for instance, after a long period of high pressure, there is a sudden fall.

For this reason the conditions for the inflow of the dangerous gases into the workings may be formulated thus:

(1) Determining the presence of the long-continued high pressure on the Continent, or of an earthquake in any part of the world.

(2) The resulting sudden reduction of atmospheric pressure.

Now we have before us a new fact. In the following table is shown the barometric pressure from January 10 to January 27; that is, during the period preceding the explosions in the Reden and Lievin mines:

January 10,	1907,	noon	774 mm.
" 11,	1907,	"	776 "
" 12,	1907,	"	780 "
" 13,	1907,	"	777 "
" 14,	1907,	"	777 "
" 15,	1907,	"	777 "
" 16,	1907,	"	777 "
" 17,	1907,	"	778 "
" 18,	1907,	"	779 "
" 19,	1907,	"	778 "
" 20,	1907,	"	778 "
" 21,	1907,	"	778 "
" 22,	1907,	"	772 "
" 23,	1907,	"	776 "
" 24,	1907,	"	774 "
" 25,	1907,	"	772 "
" 26,	1907,	"	771 "
" 27,	1907,	"	774 "

From this it is seen that between the 12th and the 24th of January the pressure was constantly about 780 millimeters or 30.7 inches; and here commenced the variations, but with a constant tendency to fall. This is the most critical time, during which all those in charge of the mines should be warned, and all precautions taken, as after many experiments the author has shown that when the barometer commences to fall suddenly, it is already too late—according to his experiments, from four to six hours.

In the case in question there was a sudden and marked fall in the barometric pressure on the day of the accident itself (January 28). This lasted two days, and reached the lowest point January 30. Sunday noon, January 27, the pressure was still 774 millimeters (30.47 inches); then the pressures were as follows:

At 2 o'clock,	P. M.		773 mm.
" 6	"	"	772 "
" 8	"	"	771 "
" 10	"	"	771 "
January 28, midnight			770 "
At 2 o'clock,	A. M.		769 "
" 4	"	"	769 "
" 6	"	"	768 "
" 8	"	"	767 "
" 10	"	"	766 "
" 12	"	noon	765 "
" 2	"	P. M.	764 "
" 4	"	"	763 "
" 6	"	"	763 "
" 10	"	"	761 "

On Tuesday, January 29, at midnight, it was 760

millimeters; 2 A. M., 759; 4 A. M., 758; 6 A. M., 757 millimeters; and on Wednesday, January 30, at midnight, 754 millimeters.

The figures for Sunday and Monday are typical and showed the coming danger so plainly that all the directors of the Belgian anthracite mines, and also engineer Reaumaux of the French mines at Lens (on the Belgian border) ordered all work in dangerous workings to be stopped.

In this connection, the Etoile Belge says: "The observatory in Uccle telegraphed to the various mines in the Charleroi and Centre basins, warning them of approaching danger. At once all precautions were doubled, the ventilating fans were run fast; besides this, all work was stopped where there was special danger of gas. These precautions were continued until there was information that the danger had gone by."

But in Germany these precautions were not taken; so that in the Reden mine near Saarbrücken, there was a terrible explosion; and at the same time one in the French mine Lievin in the Pas de Calais basin.

The natural result of this new lesson is that any Frenchman, as any Belgian, must know the times of high atmospheric pressure and pay special attention to the critical moment of the depression which follows. It is desirable that in France there shall be for this purpose a seismic and meteorological observatory especially for the anthracite mines, as there is in Belgium, in the cities of Uccle, Quénast, and Frameries. The danger from such explosions must be combated by scientific means and the possibility of mine explosions must be foreseen and guarded against, just as in the case of ordinary atmospheric storms.

THE NADIR OF TEMPERATURE.

WHAT THE PHYSICIST HAS DONE IN ATTAINING GREAT COLD.

Sir James Dewar, F.R.S., recently lectured at the Royal Institution on "The Nadir of Temperature and Allied Problems." "Liquid hydrogen was shown here ten years ago," Sir James remarked, in the course of his discourse, "and we are not further with helium than we were some years ago." Sir James impressed upon his audience the manifold difficulties of all attempts to lower the actual nadir of temperature, and referred also to the pecuniary sacrifices that will have to be made finally to settle the fundamental problem whether or not helium is, after all, a permanent gas.

When first lecturing many years ago in the Royal Institution Theater, Sir James Dewar spoke on the zenith of temperature and the efficiency of solar heat; since then he has been working in quieter regions. Our absolute scale of temperature depends upon gas thermometry. For demonstrations thermo-junctions coupled with galvanometers are more convenient than thermometers. With the aid of thermo-junctions lowered into air boiling away in Dewar jackets, he showed that the boiling-point of air was 88 deg. C. (on the absolute scale), and that this temperature was hardly lowered when air was blown through the liquid; the vessels were placed in front of the lantern, so that the spectators could watch the effect. When, however, hydrogen was bubbled through the liquid air, the thermometer at once went down about 5 deg. Then the liquid air was exhausted; the temperature fell rapidly to about 70 deg., and more slowly to 65 deg.; that was the limit attainable by these means. In these experiments two vessels had been used, both filled with liquid air. The air in the one was next replaced by liquid hydrogen, when the thermo-junction indicated 20 deg.—the boiling point of hydrogen. On the hydrogen being rapidly exhausted the thermometer again indicated a fall through three and more degrees. In this way we could come down to 15 deg. C. absolute, at which temperature the hydrogen solidified. When air was admitted, so that heat gained access, the hydrogen melted again.

This temperature of 15 deg. absolute, Prof. Dewar proceeded, is our actual nadir—the lowest temperature we can maintain. What do these figures mean comparatively? Hydrogen boils at 20 deg., air at 88 deg.—more than four times as high a boiling point; the temperature in the theater was nearly blood heat, about 300 deg. absolute, fifteen times warmer than the boiling hydrogen. If we go fifteen times higher again, we come to 4,500 deg.—nearly the temperature of the sun. When we drop liquid air on another liquid, a temperature step from 300 deg. down to 88 deg., the liquid air assumes at once the spheroidal state and rushes about on the liquid. In the light of the lantern it looked like a tadpole, or a nucleus with a cometary tail (the mist cloud of the condensed moisture of the air, following the darting drop of liquid), reflected from the wall of the cup or running along the wall. The experiment was also made with liquid hydrogen poured on the liquid air; the temperature step was from 88 deg. down to 20 deg., the ratio again about 4 : 1. The experiment was less striking possibly, because it all passed in a few seconds, although 10 cubic centimeters of liquid hydrogen were applied each time. The liquid air had been boiling; when the hydrogen was poured on, all was clouded over for a second, then dark cloud patches with washed-out edges, somewhat like thunder-clouds, flashed over the surface, which a moment later appeared rippled as if under a breeze, but quiet; the boiling had stopped—the hydrogen was too cold.

The rapidity of the phenomenon, Sir James continued, was suggestive of the difficulties we had to face when attempting to lower the nadir; other demonstrations exemplified this difficulty. Two vacuum jackets—alike in all respects except that the one was coated inside with silver, the other with blacklead sulphide—had been charged with liquid air, and connected by a pipe, so as to be under the same pressure. The air was allowed to distill, first from the one and then from the other vessel; it took 35 seconds to obtain 50 cubic centimeters from the silver vessel, and 7 seconds with the lead sulphide. The experiment demonstrated the importance of radiation in low-temperature research. A film of nickel, from Mond's nickel carbonyl, would be nearly as good as silver; it is not merely a question of radiation, of course, but the lecturer did not discuss that part of the problem.

All the oxygen now used in the London hospitals, Prof. Dewar continued, is obtained from liquid air and is much purer than other commercial oxygen, and Linde sends his liquid air all over Germany. Sir James showed how air becomes cooled on expansion with an old apparatus of the Cailletet type; air was compressed by a pump, cooled to absorb the heat of compression, and then expanded; the thermometer went down some 15 deg. Wroblewski had in 1888 first seen a mist of hydrogen produced by this instantaneous method. With helium both Sir James, in 1901, and K. Olszewski, of Cracow, in 1905, had failed to observe any condensation by adiabatic expansion. The following table summarizes the results of their experiments:

ADIABATIC EXPANSION OF HELIUM AT TEMPERATURE OF SOLID HYDROGEN.

	Initial Pressure, Atmospheres.	Final Pressure, Atmospheres.	Temperature, Degrees, Cent. Absolute. Olszewski.	Dewar.
Olszewski ...	180	40	7.6	11.7
Dewar	80 to 100	20	5.8	8.9
Dewar	..	10	4.4	6.7
Dewar	..	5	3.3	5.1
Dewar	..	1	1.7	2.7

Thus Olszewski thought he had reduced his temperature down to 1.7 deg. above absolute zero. Yet neither he nor Sir James had seen any indication of liquefaction. Olszewski, in fact, regarded helium as non-condensable, Sir James remarked later on; and it would be a most important addition to our knowledge to have this question decided. There are, however, several facts that would help to account for their failures to observe any condensation. The refractive index of helium and its latent heat are very small, the latter only one-seventh of that of hydrogen probably. When they arranged the apparatus on the circulation principle, with several regenerative coils and a pin-hole nozzle for the liquefaction of hydrogen, they started from air at 65 deg., and had to go down to 20 deg. Assuming the boiling point of helium to be 5 deg. or 6 deg., to which several observations pointed, they should have started from 15 deg. to have had the same temperature fall of 3 : 1. But that would have required an enormous plant, and with the mass of gases and the time required, the fight against any influx of heat from outside became harder. We have no intermediate fixed point between 65 deg. and 20 deg. or 15 deg. C. absolute. That descent is big; in order to keep the circulation up for four minutes in his apparatus, about 6 liters of hydrogen had to disappear. During all the time of the operations the impurities of the gas would have accumulated.

There were other difficulties to be overcome before they could commence working their apparatus. Hydrogen was cheap enough, helium very costly. For years his supply had all come from the King's Well at Bath, which gave off a gas (largely nitrogen) containing 1/2,000 of its volume of impure helium. He had to deal with very large volumes, and after years of work he had once lost his treasured store of helium, and had nearly lost it another time. We know now that helium is more common than we had at first thought. Our atmosphere contains 1/40,000,000 of helium, and in several springs it is more abundant than at Bath. The gases given off by certain springs in France contain more than 2 per cent of helium, and 2 per cent of helium has also been found in the natural gas of a North American town. We cannot isolate that helium, unfortunately. But looking forward to the time in which he would have his large holders full of helium, Sir James could not say at present whether with the means at our disposal the regenerative method will prove successful.

For these and other reasons, the lecturer went on, he has had recourse to charcoal, which has proved a powerful absorbent for most gases. With helium, however, the absorption only begins at the lowest realizable temperatures; but when we came to the boiling point of hydrogen, charcoal absorbs 200 times its volume of helium, and the trend of the curve suggests that helium would, at its own boiling point, be absorbed to the same percentage as hydrogen at its boiling point. This absorption of gases by charcoal is accompanied by an evolution of heat, as regards which Sir James pointed to the following table:

HEAT EVOLUTION DETERMINED BY CHANGE OF THE PRESSURE-CONCENTRATION CONSTANT.

	Molecular Latent Heat.	Temperature, Absolute, Deg. Cent.
Helium	4.6 × 105	18
Hydrogen	114	
	436	78
Nitrogen	665	82
Oxygen	684	
Carbon dioxide	1,326	180

The direct value for hydrogen, as measured in the liquid-air calorimeter, which Sir James described in his discourse of a year ago, is 4.6 × 426.

Having very briefly dwelt on the high degrees of exhaustion which the use of charcoal permitted us to effect at very low temperatures, and their determination—matters explained and so splendidly demonstrated last year—the lecturer passed to some experiments which seemed to indicate that charcoal, though it can maintain a high vacuum, is subject to leaking all the while. This was the phrase we understood Sir James to use; the interesting experiments rather appear to us to show—what needs no particular proof, of course—that the rate of gas absorption by charcoal is not unlimited. Sir James had no time to give a full explanation. A vacuum discharge bulb was connected to a T of glass leading on the one side to the branch containing the charcoal, which was lowered into liquid air, and on the other to a very fine capillary tube, more than 1 foot in length, bent to a U, and communicating with the outer air, when a stop-cock was opened. In spite of this communication the vacuum was high, so that the electric discharge would hardly pass; but when the capillary tube was also lowered into liquid air, the discharge flashed up for a time. The air entering the bulb had to pass through the capillary; the cooling did not affect its viscosity much, but it decreased its density considerably; more air could hence pass through the capillary per unit time. The stop-cock was kept closed during this period, and it was only the little air that had collected in the inside of the cock which was concerned in the experiment. The other demonstration was still more striking. A little thoria was fixed on one of the electrodes of a Crookes bulb, which was provided with a downward extension, containing the charcoal, and a horizontal branch closed by a piece of rubber tubing stopped with a glass rod at the free end. The discharge of an induction apparatus giving a 4-inch spark would not pass after the charcoal had been cooled. But the air leaking in through the piece of rubber tubing impoverished the vacuum, the air contained in the thoria probably helped, and the discharge passed; the thoria flashed up brilliantly for a moment as if on fire, to become dull again almost immediately afterward, because the gas pressure had become too high. But when the stop-cock shutting off the charcoal from the bulb was opened, the charcoal was ready to absorb any fresh air leaking in, and the flash-up repeated.

Another curious experiment had previously been interposed. Two little balloons were suspended from the same glass tube, and thus under the same gas pressure, each in its own Dewar jacket; each was half full of liquid air. The one balloon was made of glass, the other of rubber, 0.02 millimeter in thickness only, but quite stiff, owing to the cold liquid in it. With the lantern light behind them, both balloons looked very much alike, the rubber a little darker than the glass. When air was admitted into the jacket of the rubber balloon, the liquid inside it began

to boil strongly and the balloon was drawn out to an oval shape.

Sir James Dewar concluded his discourse by an experiment demonstrating that a liquid can be solidified with the aid of a condenser at four times its own temperature. The apparatus consisted of a tube containing liquid hydrogen, suspended in a Dewar vessel charged with liquid air; on the other side was the charcoal tube, which was lowered into liquid air. The hydrogen tube was placed in front of the lantern. The hydrogen was seen to boil quietly. After a while it began to boil rapidly, and to solidify at the top; but it would not freeze until the cap was put on the lantern to stop the strong heat radiation. Then it froze to a froth of snow and bubbles.—Engineering.

AN EXPERIMENTAL MODEL BASIN.—II.*

A BRIEF DESCRIPTION OF ITS FUNCTIONS AND OPERATION.

BY NAVAL CONSTRUCTOR R. H. M. ROBINSON, U. S. NAVY.

Concluded from Supplement No. 1698, page 38.

MODELS are as far as practicable made of the standard mean immersed length of 20 feet. The length over all is usually somewhat greater. The model-making apparatus is designed with the idea of working from a body plan. Having a correct body plan upon a certain scale, sections of a 20-foot model corresponding to the sections in the body plan are first determined, using an eidograph, and with the usual scales for drawings and sizes of vessels, it nearly always involves enlargement. The eidograph works upon a table covered with a sheet of glass.

Having properly adjusted the length of arms by means of the scales provided, the pointer on the short arm is run around the sections of the body plan, the pencil on the long arm describing the sections desired upon pieces of paper. These paper sections are used as patterns for use in cutting out the wooden sections for the former model. These are clamped in their proper relative positions upon an iron table and a skin of round strips of wood nailed securely to them. Fig. 3 shows this skin partly in place. This completes the "former model," as it is called, except that plaster is later applied as described below. Its ends are not made to accurately represent the vessel, as it has been found more desirable to rough finish only from the former the ends of the final model and finally finish them by hand.

While the former model is building, a wooden block is built up of white pine planks about 2 inches thick sawed hollow and glued together hot under heavy hydraulic pressure. This block is so proportioned that when the finished model is cut from it, the wood will be left amply thick, generally not less than about 2 inches. Additional thickness is not especially avoided, as the models require ballast in every case. The former model and its corresponding block are now secured in the model-cutting machine, the former model being below. As may be seen from Fig. 4, the roller below rolls over the former model, and the saw above, driven at high speed, is constrained by the balanced link work to move exactly above and at a uniform distance from it. The sizes are so arranged that the saw does not cut within one-eighth of an inch of the intended finished surface of the model. There are two traversing cutter heads, one on each side. Each is traversed (by an electric motor) three-quarters of an inch or so at a time and then a saw cut made. Then the superfluous wood is knocked off, the interstices between the battens of the former model plastered with plaster of Paris to give a smooth surface, and a rotary cutter substituted for the saw, with a corresponding roller.

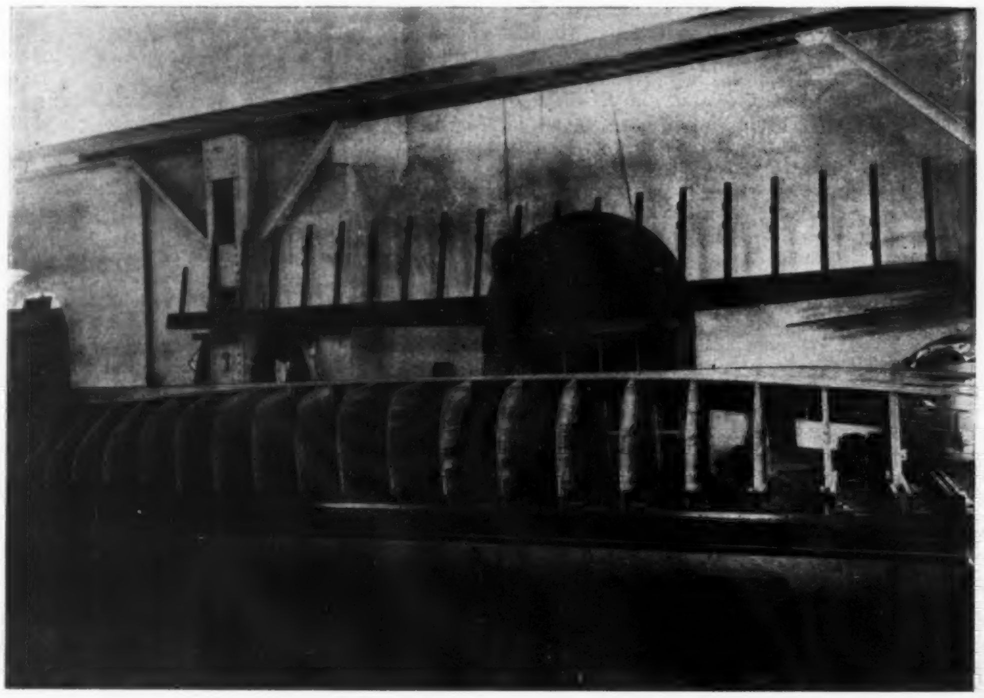

FIG. 3.

* For the greater part of the description of the United States model basin and the apparatus, contained herein, I am indebted to the Society of Naval Architects and Marine Engineers and to Naval Constructor D. W. Taylor, U. S. N., with whose permission they have been used.—R. H. M. R. Copyright by the United States Naval Institute, Annapolis, Md., and reprinted by permission from the Proceedings of the United States Naval Institute.

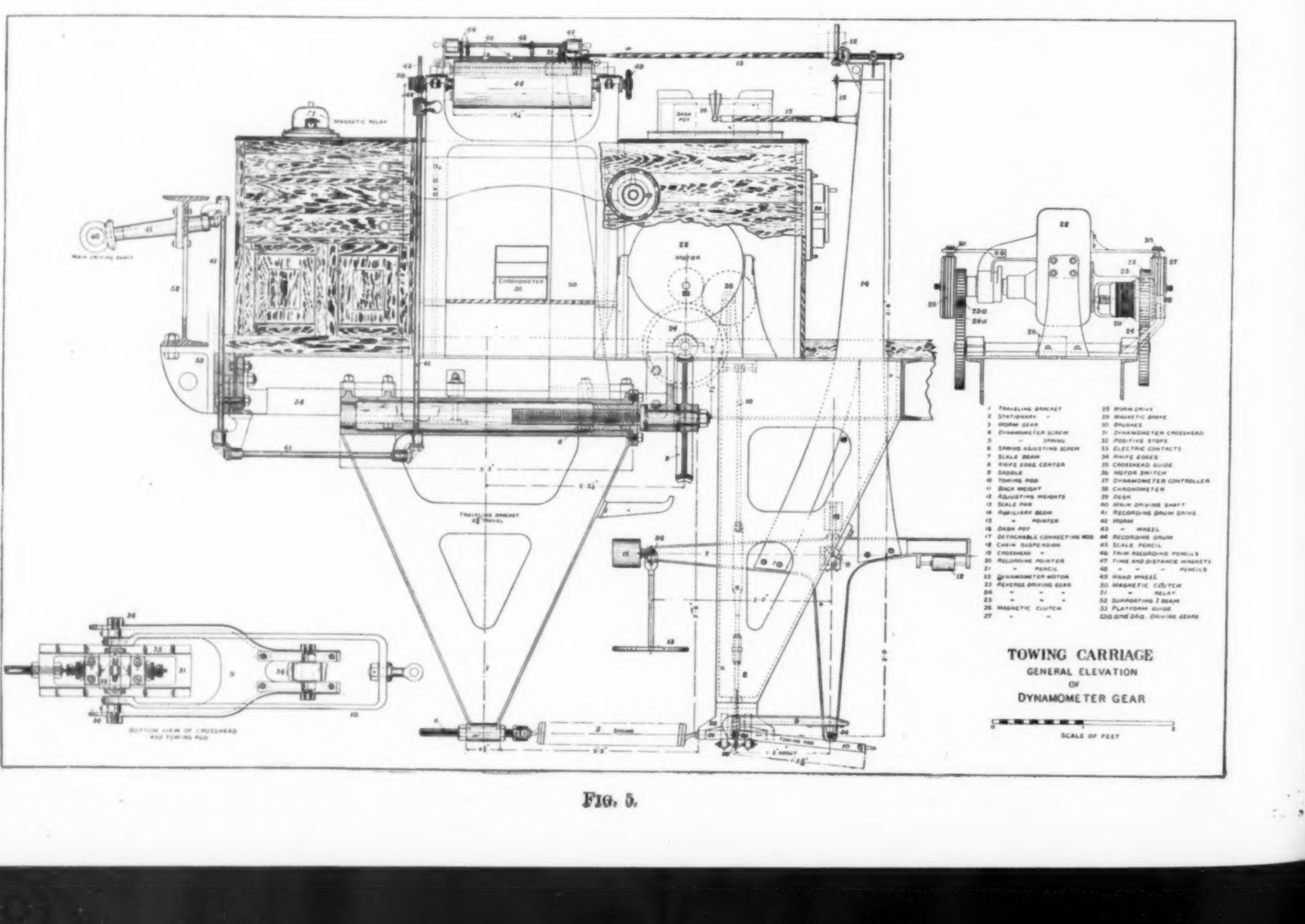

FIG. 5.

This cutter rough-finishes the model to very near its exact size. The model is then removed from the machine and finished by hand, the ends, which are left quite rough, being also shaped by hand from paper patterns or light wooden templates obtained from the lines. Sanded disks, driven at high speed by an electric

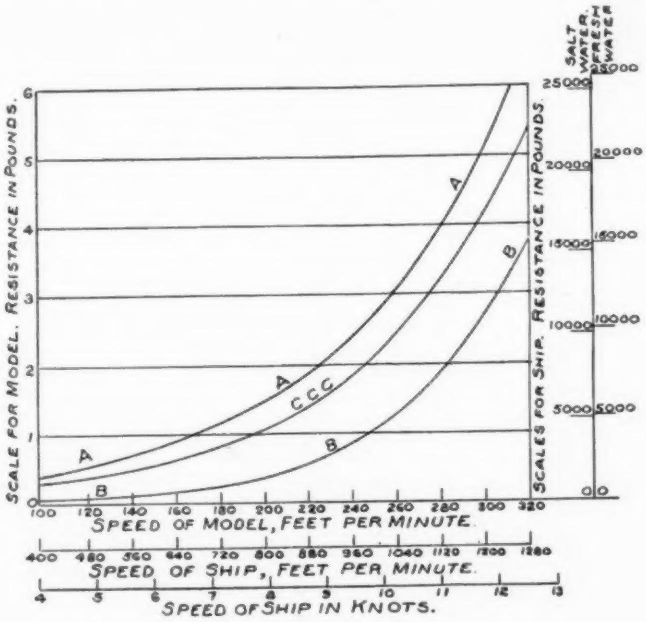

FIG. 6.

motor, are used to finish. The models are carefully painted, inside and out, and a standard varnish finally applied to the outside to get a uniform surface.

Before being taken to the basin, the models are carefully measured.

From the results of measurement, a body plan is drawn and compared with the original lines to insure that the model accurately represents the ship. All calculations at the model basin are made from actual lines of the models.

The tops of the completed models are parallel to their designed water lines, and with the level straight-edges fitted in the south end of the basin, it is easy to determine the exact trim of the model when afloat.

All trials are run by weight and draft is used only as a rough check. Before beginning a trial a model is suspended to one of the cranes on the carriage, and weighed. It is then ballasted until its weight in fresh water corresponds to the desired displacement of the ship which it represents. After a trial the model is weighed again for checking after the ballast has been removed. Models are handled by electric cranes, one on the forward side, the other on the after side of the carriage. The models are stowed on the galleries on each side of the basin.

The dynamometer is shown in Fig. 5. Its object is to record the resistance of the model, being towed through the water of the basin. The dynamometer is attached to the carriage which runs to and fro on rails above the water. The model has vertical plates attached to it in the center line at each end which play with very little freedom between the pointers rigidly attached to the carriage, so that with practically no friction the model is constrained to move in the same direction as the carriage and without deviation, and at the same time is free to rise and fall, or change trim. The towing rod (10) takes the resistance of the model, and the fore and aft motion of the model, relative to the carriage, is very little.

The recording drum (44) is arranged to have sheets of paper about 16 inches by 22 inches secured to it somewhat as paper is secured to an ordinary indicator drum. The drum (44) is mounted upon a shaft which ordinarily can be turned by hand by means of the little hand wheel (49). Mounted loosely upon an extension of this shaft is a worm wheel (43) driven by a worm (42) which is connected by the parts numbered (41) to the main driving shaft (40), revolving with the wheels of the carriage. An electric clutch (50) seizes the worm wheel to the shaft or releases it, so that when desired the drum can be thrown into gear and driven at a speed proportional to the speed of the advance of the carriage.

Pencils (48) in connection with the magnets (47), record upon the drum "time" and "distance." The "time" pencil is connected with a break circuit chronometer (38), and records every second upon the drum. The "distance" pencil records contact with pins spaced along the track 30.4 feet apart. This distance of 30.4 feet is 1/200 of a knot, a knot being taken as 6,080 feet. From the record of time and distance the speed could be readily calculated, but in practice it is found that the working of the drum is so accurate that the speed can be read off directly by an arbitrary scale and the distance pencil is not ordinarily used. The length of record corresponding to 10 seconds of time is measured on a special scale which gives at once the speed in knots. This scale requires calibration and changing from time to time due to wear of wheels, etc. The distance record is used from time to time to check these direct readings in order to make sure that no wear of parts or lack of adjustment has vitiated accuracy.

Paper with metallic surface is used upon the drum, and the so-called pencils are really pieces of brass wire.

Considering the dynamometer proper, the spring (5) is connected at its rear end to the swinging cross-head (31), which is suspended by rod (19), about 4 feet long, and so arranged as to swing very freely. A pin runs through this cross-head over which the towing rod jaws fits loosely. Outboard of the towing rod on this pin are vertical and horizontal flat surfaces upon which knife edges (34) in the saddle (9) bear. The cross-head moves in the guide (35) rigidly bolted to the fixed bracket (2). Its travel is about ¾ of an inch between positive stops (32). At the extreme end of the rod, just below the cross-head, are electric contacts (33), adjustable and usually set so that the contact is made on either side just before the cross-head reaches the positive stop, which is also adjustable.

The forward end of the spring is attached to a screw (6), which is secured to the lower end of the traveling bracket (1). Attached to this traveling bracket is the arm (20), carrying the record pencil (21), which then marks upon the drum the exact position of the traveling bracket and thus determines the position of the forward end of the spring. The rear end of the saddle (9) is fitted with horizontal and vertical knife edges (34), engaging vertical and horizontal surfaces on a pin attached to the lower arm of a bell crank lever. This bell crank is balanced upon knife edges (8) and carries by means of the scale beam (7) a scale pan (13). It also has attached to it the auxiliary beam (14) which is connected by double pivots to the pointer (15) which records upon the drum the position of the rear end of the spring. The distance up from the knife edge center (8) to the line of action of the pointer (15) being 5 feet 6 inches, while the distance down to the line of action of the spring is 2 feet, it will be seen that the motion of the rear end of the spring is increased at the pointer in the ratio of 2.75 to 1.

The dash pot (16) is filled with glycerine and has a hollow floating piston with detachable connection rod (17), the rear end of which engages, as shown, a pin in the bracket upon (14). The rear end is so suspended by the chain (18) that no weight is taken on the pin, and the latter has a play in the jaws of the connecting rod (17) of 1-16 inch or so.

The traveling bracket (1) is actuated by a screw (4) being rigidly held by guides as shown. The screw (4) is driven by the worm wheel (3), which in turn is driven by the worm (28). This worm is upon a shaft which carries the gear wheels (24) and (24a), which mesh with the pinion (23a) and the idler (25); the idler (25) being driven in turn by the pinion (23). These pinions (23 and 23a) are loose upon the shaft of a motor (22), which is running all the time. At the ends of this shaft are magnetic clutches (26 and 27) which grip the pinions (23 and 23a). It will be seen that when clutch (26) is in gear so as to grip the pinion (23a), the traveling bracket (1) and recording pencil (21) must move in one direction, and when the clutch (27) has hold of pinion (23), the pencil (21)

FIG. 4.

moves in the other direction. When both clutches are out, the pencil does not move, and the apparatus is so arranged that but one clutch can be in at one time.

There is a magnetic brake (29) upon the idler (25), so arranged that when neither clutch is in, a spring throws the brake in and thus promptly checks the motion of the pen when the clutch releases. When either

clutch is in, the spring is held back by a magnet, and the whole gear moves freely. The clutches can then be thrown in by hand as desired, and in addition are connected through a magnetic relay (51) to the contacts (33) at the lower end of the dynamometer cross-heads, the connections being such that when the cross-head swings against the rear contact (33) the bracket with the recording pencil (21) is screwed forward, and when contact is made forward the bracket is screwed back. This is done automatically when the switch with the magnetic relay is in.

The various electric contacts for operating the device described are all controlled by the handle of the controller (37). When the pointer is brought opposite "tension" the traveling bracket is screwed forward so as to give the spring tension. When it is brought opposite "automatic" the contact arrangements just described (33) automatically traverse the traveling bracket (1). Then as the pointer reaches "drum" the drum is set in operation, and as it reaches "time" the time pencil begins to record, and as it reaches "distance" the distance pencil begans to record. In practice, in making a run, when it is desired to begin the record, the pointer is thrown at once to the right until it reaches "distance," when all the operations above described are in.

The following process of adjusting the apparatus and calibrating the spring is used:

Before putting in the spring, the cross-head is brought to its central position by means of the balance weights (12) upon the bell crank, and care is taken that the cross-head swings in this position whether the pin securing the scale pan (13) rigidly to the scale beam (7) is in or out. The position of the auxiliary pointer (15) is then noted. There are fitted, so as to mark upon the drum when desired, a number of fixed pencils, such as (45), which can be set to record at any position. One of these, called the auxiliary zero pencil, is now set so as to indicate always the position of the auxiliary pointer (15) when the cross-head is central and everything balanced.

Next the spring (5) is slipped into place and a corresponding back weight (11). The record pencil (21) is then brought to a convenient position for zero of the main scale, and a scale pencil set to mark always this zero. By adjusting the screw (6) forward or back, as may be required, the auxiliary pointer is brought back to its zero. When this is the case the back weight (11) gives the spring a certain initial tension by means of the saddle (9) and cross-head (31), while at the same time the cross-head is swinging freely in exactly its natural or zero position. Supposing the spring in use is a forty-pound spring, or a spring which at its maximum extension of 9 or 10 inches will record 40 pounds. It will be noted that the extension of the spring is not from its natural position of equilibrium or from zero tension, but from its arbitrary zero position, the amount of tension at the arbitrary zero depending upon the amount of back weight used.

It has been found that the springs are more reliable if given an initial tension by the use of such a back weight. The scale pan (13) is next allowed to swing freely, and a weight of ten pounds placed upon it. This extends the spring until the cross-head brings up against the positive stop. The bracket (1) is then screwed forward by throwing the motor in gear until the auxiliary pointer again comes to zero. A scale pencil (45) is now set to mark the position of the recording pencil (21). Twenty pounds is now placed upon the scale pan and equilibrium again restored by screwing the traveling bracket forward. Similarly thirty and forty pounds are used. The scale pencils, such as (45), now record upon the card lines which correspond to extensions of the spring, measuring 10, 20, 30, and 40 pounds. The weights are removed, the recording pencil (21) returned to about its zero position, the scale pan (13) clamped in its zero position, and the work of adjustment and calibration is complete.

The model is then attached by the towing rod (10), which it will be seen (although it may be at an inclination) transmits to the spring only the horizontal pull upon it, the resistance of the model being all in a horizontal plane. It is customary to start a series of runs with the lower speeds and work up by degrees to the highest speeds, plotting roughly the results as they are obtained after each run. In this way, knowing the speed of a run about to be made, the approximate corresponding resistance can be guessed at very closely, and it is the practice to set the record pencil (21) approximately at this position before making the run, so that the automatic appliance may be called upon to traverse it as short a distance as possible.

It is evident that if, during the run, the auxiliary pointer swings from its zero position, the indication of the record pencil (21) must be corrected according as the auxiliary pointer is above or below its zero position. The correction is evidently 172.75 of the deviation of the auxiliary pointer, supposing the extension of the spring to be such that its stress diagram is a straight line. It is found in practice that the stress strain diagrams for the springs used are practically straight lines. The operator can, however, after experience and practice, by means of a touch of "tension" or "release," bring the auxiliary pointer very close to zero during the majority of runs, so that the automatic devices do not come into play at all, although thrown into gear.

Plotting.—Supposing the difficulties to have been overcome, we can plot the results of towing experiments upon a model in the shape of a curve, such as *AAA*, in Fig. 6, showing the resistance in pounds of the model plotted upon speeds as abscissæ. This curve represents the total resistance, made up, as we know, of skin resistance, eddy resistance, and wave resistance.

We also know that the latter two alone (eddy resistance and wave resistance), constituting the residuary resistance, follow the Law of Comparison.

The first step, then, is to deduct from the total resistance the skin friction, which is calculated from the wetted surface and the results of experiments on planes of various character. Setting down the skin friction from the curves *AAA* in the figure, we obtain the curve *BBB*, representing the residuary resistance of the model. Now we know from the Law of Comparison that this curve also represents the residuary resistance of the ship, provided the scales of speed and resistance are suitably changed.

In the case shown by Fig. 6, the model was 1-16 the size of the ship; hence, corresponding speeds of the ship and model are in the ratio $\sqrt{16} : 1$ or $4 : 1$, and residuary resistances at corresponding speeds are in the ratio $16^3 : 1$, or $4{,}096 : 1$.

Drawing in the scales for the ship as shown, the curve *BBB* represents the residuary resistance of the ship in either fresh or salt water, according to the scale used.

Salt water resistance $= 1.026$ (fresh water resistance).

It is now necessary to calculate the skin resistance of the ship, and set it up above *BBB*, to obtain the curve *CCC*, which represents the total resistance of the ship.

From the above it is evident that the relative resistances of different forms of models may be obtained and plotted in such form as to be readily comparable.

To obtain an estimate of the horse-power required to drive a given form of ship at certain speeds these resistances and speeds may be readily converted into horse-power by the formula:

$$\text{H. P.} = \text{foot-pounds per minute} \div 33{,}000.$$

The figures so obtained permit plotting a curve of effective horse-power or E. H. P. required.

The tabulation and careful consideration of results of many experiments and trial trips permits the determination of a factor giving the ratio between indicated horse-power and effective horse-power, and assuming, after due consideration of the conditions obtaining, a value for this factor, a curve of probable indicated horse-power or I. H. P. may be obtained.

I. H. P. is an expression too well known to require defining.

In the case of turbines, the measure of power obtainable from the completed installation is taken from the shaft and therefore becomes brake horse-power, or B. H. P., and the factor giving the ratio between B. H. P. and E. H. P. will differ considerably from that giving the ratio between I. H. P. and E. H. P.

The foregoing deals only with a small portion of the functions of the experimental tank, which is of value for a wide range of experiments in connection with ship resistance and ship propulsion.

WHAT THE GOVERNMENT IS DOING TO SAVE OUR NATIONAL RESOURCES.

The startling facts recently detailed at the White House conference with the governors of the States concerning the tremendous waste in the use of the natural resources of the country, and the dire predictions of their early exhaustion, have not only been realized for a number of years by the government experts, but a systematic effort has been going on to stop these drains on the future prosperity of the country.

The United States Geological Survey has been an important factor in this movement for many years; and while its work has been to a certain extent altruistic, in that the immense benefits will come to the generations of the future, it has already saved millions of dollars' worth of resources for the people of today. The Survey's geologic and topographic work has resulted in an inventory of the natural resources, a stock-taking such as a prudent manufacturer takes once a year. This has disclosed the waste that has been going on, and led directly to the conference of the governors. The study and classification of the coal deposits of the United States, and especially those on the public domain, have established the value of these coals, and have prevented the thoughtless disposal of the 50,000,000 acres of government coal lands. The values of the mineral deposits on government land have been approximated to such an extent, that it will now be impossible to dispose of them without getting a fair return.

While there have been many immediate benefits from the topographic work and a study of the water resources of the country, their value to the people will be many fold greater in the near future. Without an accurate topographic survey of the land and water, the contemplated improvement of the waterways, the drainage of swamps, and the great irrigation projects would be impossible. The work already done along these lines will push these big improvements forward several years, and result in the saving of much money.

In its endeavors to check the great waste of the natural resources, the Survey a few years ago extended its field by taking up the subject of the utilization of the fuels of the country, and so fruitful have been these investigations, that there is every promise of a saving of millions of dollars within a short period. These investigations appeal directly to the manufacturer, the business man, and the consumer, for they show him how to realize immediate economies he never dreamed of before.

Authorized to test the fuels owned by or for the use of the government itself, the Survey has made a number of discoveries of the greatest importance to the entire people. At the government's fuel-testing plant, it has been shown that the gas engine is capable of generating from two and a half to three times as much power, using a given amount of coal, as can be obtained from a steam engine. This means, it is declared, that a 600-horse-power gas engine will save $5,000 a year in its coal bill over the same power steam engine, and that the saving on a 6,000-horse-power gas engine ought to amount to $72,000 a year.

The gas engine has also opened the way for the use of millions of tons of low-grade fuel, much of which has heretofore been thrown away as useless. The tests have shown that coals, practically valueless under steam boilers because of their high percentages of impurities, have generated sufficient power in the gas engine to render them of high commercial value. Coals as high in ash as 45 per cent have been used successfully in the gas engine.

In the West, where the supply of high-grade coal is inadequate, the low-grade lignites (the poorest form of coal) of North Dakota developed as much power when converted into producer gas as did the best West Virginia bituminous coals when used under the boiler of a steam engine.

To the West this discovery of the government scientists is of the utmost importance. It makes possible the introduction of cheap power, and therefore the establishment of an industrial empire of immense proportions. There are many million acres of lignites in the West, an almost inexhaustible supply of fuel that so far has been practically useless, the people being compelled to send a great distance for their coal and pay big freight charges on what they did use.

In the average steam engine to-day, but five per cent of the coal energy is transformed into work. In the gas engine, this percentage of efficiency is twelve and a half per cent. The coal used in generating power in the United States last year amounted to about 500,000,000 tons. With the universal use of the gas engine, it is estimated that at least 100,000,000 tons of this coal could be saved.

In testing the efficiency of coals under the boiler of a steam engine, the Survey engineers suggest still another way to save the fuel. Recent experiments indicate that boilers ought to perform two or three times the work they do now. In New York city, a certain large corporation has almost doubled the capacity of its power plant by placing furnaces in the rear of its boilers as well as the front. This was done at a saving of several hundred thousand dollars, as it would have been necessary to purchase additional land held at a high figure to carry on the work.

The tests of different coals under the steam boiler at the government plant have also showed the possibility of increasing the general efficiency of hand-fired boilers ten to fifteen per cent over ordinary commercial results.

The Survey is also engaged in a general analysis of the coals of the country. These analyses have resulted in the government purchasing coal on definite specifications based upon its heating value. Under this system a better grade of coal and coal better adapted to the types of furnaces in the government buildings has been obtained without any increase in cost, which in itself is a saving to the government. These investigations, by suggesting changes in equipment and methods, are also indicating the practicability of the government's purchasing cheaper fuels, such as bituminous coal and the smaller sizes of anthracite, instead of the more expensive sizes. With new boilers in the heating plant of the State, War, and Navy Building in Washington, $15,000 is now being saved each year in the coal bill for this building alone. Many power plants are now buying fuel on specifications, and have obtained increased efficiency as a result of the government's investigations. These tests of the coal will aid manufacturers, wherever situated, to save money in the purchase of coal, for they will enable them to learn where they can buy coal that is best suited to their purposes.

The government has found still another way of conserving the fuel resources in the briquetting of coal. The investigations show that in the near future the great quantities of waste coal seen about every mine and the low-grade coal that is now being left in the mines will be utilized in the generating of power and for locomotive power and domestic heating. Successful tests of briquettes were recently made on two railroads. The briquettes, which were made from the slack of high-grade bituminous coal, showed an economy of twenty per cent over the same lump coal, not taking into consideration the cost of making the briquettes.

At the government fuel testing plant at Denver, Col., investigations into the washing and coking of coal have been carried on for a year with much success. In the washery plant, it has been shown that coals were greatly improved by washing at the nominal cost of from three to ten cents a ton. In recent experiments, the experts have succeeded in making coke out of several coals that have been regarded as non-coking. Of thirty-seven samples tested from the Rocky Mountain region, all but three produced good coke, though a number of these were considered non-coking coals. When the metallurgical interests of the West are noted, the importance of these investigations will be realized.

THE MARINE GAS ENGINE.

ITS DEFECTS AND ITS MERITS.

SINCE the paper enforcing the potentialities for success possessed by the marine gas engine was communicated to the Institution of Naval Architects about a year ago by Mr. James McKechnie, of the Vickers Company, interest in the subject has increased. Progress toward the solution of the problems has been made, principally in details. But we are yet some way short of the bold step attributed by some of the daily papers to the Admiralty of contemplating the adoption of gas engines in the battleship to be laid down at Portsmouth under this year's naval programme. The engineering authorities at the Admiralty prefer—and very properly so—to proceed upon sure basis, and the adoption of a gas-engine propelling installation will not be undertaken until exhaustive trials have been made, ashore and afloat, with the two small gas-engine sets still under construction. These two engines, with their producers, have been under order for a long period, a fact suggestive of the difficulties connected with the application of the system for marine purposes. For land stations, principally for the driving of electric generators, engines having cylinders developing 1,000 and even 1,500 brake horse-power are working satisfactorily; but there are relatively very few gas engines driving ships, and the largest of these is of almost insignificant power. In this country, Mr. William Beardmore, of Glasgow, has done much toward practical tests on board ship. The promise of success is now greater than in the earlier stages, because the great advantages of the system are now realized and the exact nature of the difficulties to be overcome is recognized. Once a diagnosis is correctly established, the cure is rendered more easy.

The advantages to be obtained from an installation of large size for marine propulsion are a saving of one-third of the space occupied by machinery, and a reduction of the total weight of machinery of possibly one-fourth. While the engine itself would have to be much heavier than a steam engine of the same power, the necessary gas producers would be much lighter than the steam boilers. As the gas engine and producer have a thermal efficiency about double that of the combined thermal efficiency of the steam engine and boiler, it should be possible to get a horse-power at the propeller for 1 pound of coal per hour, and also to obtain it from a cheaper grade of coal than can be used to advantage in a boiler. The last-named advantage will appeal strongly to owners in the mercantile marine, as it will enable the fuel cost of transport per ton-mile to be considerably reduced. Gas producers, when once charged, will go on making gas for several hours without further attention. In Beardmore's tests on board ship the producer, once charged, runs for ten hours without attention. The same large force of stokers needed for a steam installation of any size will not therefore be required. Where there are many producers they would be charged in succession, and not more than two or three in any one watch. There would be considerably less than one-quarter the amount of ashes to handle in a given time, and there should be no clinker at all. There would be no smoke, and, therefore, the large funnels, with their wind resistance, would not be present. The space usually occupied by uptakes would also be saved. This advantage would be of considerable value to naval vessels by enabling them to almost get into range before their presence could be detected. It must be remembered that each and every cylinder in a gas engine is a complete engine in itself; and should one or more break down, the disabled cylinder could be put out of operation, and the propeller turned as long as there was a single cylinder left in working order. It is only necessary to remove the connecting rod, and the rollers that are operated on by the cams, in order to disconnect a cylinder—a much lighter job than would be required in the case of a steam engine, though the weight to be handled might be greater.

The disadvantages of gas propulsion for marine use, though many in number, are not by any means insurmountable. The chief objection seems to be the very high temperature that obtains in the cylinders when they are of large size, and the consequent liability of the valves to score and give trouble, finally resulting in a complete temporary stoppage, which would be exceedingly inconvenient, if not dangerous, at sea. There are several methods of reducing this excessive temperature, such as making the engine of relatively long stroke, diluting the charge with a surplus of air or some of the exhaust gases, increasing the volume of water circulating in the jackets and pistons, or injecting water into the cylinder during the combustion, etc. Valves, if of large size, can readily be water-jacketed. They can also be double-seated, and thus cause the speed of the hot gas through them to be reduced, and the work required to lift them to be lessened. Another objection has been the great size and weight of the crankshafts and connecting rods, framing, etc., in order to withstand the heavy and violent shocks incidental to all gas engines. Here again the relatively long stroke engine will score, and by adopting a cycle of operations in which heat is added at constant pressure rather than at constant volume, the violence of the shocks can be reduced, and a lower temperature of combustion obtained at the same time. It has been considered a disadvantage that most gas engines are fitted with trunk pistons, and that therefore the connecting-rod pin is inaccessible, and the piston, when worn, has to be entirely renewed. But when gas engines are built specially for marine use, they will be of such a size that they will have thin water-cooled pistons, be double-acting, and be fitted with the ordinary crossheads and slides used upon steam engines; or if trunk pistons are used, they will be fitted with adjustable shoes to take the wear in the wake of the connecting-rod pin.

It is generally considered to be a difficult matter to make a gas engine reversible, but this is only because it has generally been attempted with the usual revolving cam gear, and on engines of comparatively small size. On large engines, oscillating instead of revolving cams can be used with advantage, and these can be operated by the well-known Stevenson link motion or by the Joy, Marshall, or other radial reversing valve motion, worked by compressed air when the engines are very large.

A special compressor, driven by an independent gas engine, will always form a part of a marine gas engine installation, because compressed air will be required for starting the main propelling engines, blowing the whistle and siren, working the reversing engine, circulating and other pumps, steering engine, capstan, deck winches, ash hoists, etc., which are now part of the recognized outfit of the modern steamship. Under certain circumstances, all this work might be done by electricity, in which case a separately-driven electrical generator would take the place of the air compressor. A disadvantage of the gas engine for marine propulsion is its want of flexibility in the rate of revolution at which it can be driven, but there are several ways in which this can be met, such as cutting off the gas supply to one or more cylinders, building the engine in two or more distinct units which can be readily connected up or disconnected, applying the total power on three or more shafts, so that one may run ahead and two astern, or *vice versa*, so that a ship of large total power may be run at very slow speed when necessary.

A mechanical disadvantage of the gas engine, when used for marine propulsion, is the uneven turning moment, especially when run on the four-stroke cycle. It is, of course, much better on the two-stroke cycle, but as in the latter case twice the amount of hot gas has to pass through the exhaust valve in a given time, special provision has to be made to meet and overcome this difficulty. Three double-acting cylinders, acting on cranks at 120 degrees apart, is probably the smallest unit that can be relied upon to work satisfactorily, and even then it would be necessary to employ a flywheel.

Another mechanical difficulty is in so regulating the power that it shall follow the sudden variation in the resistance, due to the propeller being partially lifted out of the water when the vessel pitches; but some form of high-speed centrifugal governor arranged to cut out or throttle the gas supply, relieve the pressure in the cylinders, cut out the ignition, or a combination of two or more of these methods, should be able to meet the difficulty.

What to do with the exhaust from the marine gas engine is also quite a difficult problem to settle, but as the object sought to be attained is both to cool and reduce the volume of the exhaust gases as rapidly as possible, some form of surface condenser, in combination with an injection of part of the cooling water into the exhaust pipe, ought to meet the case. The cooled gases could also be afterward discharged overboard below the surface, and thus secure perfect silence. Objection has been made to the gas producer on board ship that poisonous gases are liable to leak out and either kill the crew or cause disastrous explosions, but if operated under the suction system this does not hold, since any leak would be into, and not out of, the producer. If the producers are operated on the pressure system, it is only necessary to surround the producer and all the gas pipes with an outer airtight shell, and force the supply of air through the intervening space on its way to the producers. In this way any leak that could occur would be pure air, either into the ship or into the producers or gas pipes. If more than one producer were in use, it would be the duty of the attendants to regulate the amount of gas furnished by each, in accordance with the reading of a pyrometer fitted to each one, so that the temperature of combustion in each was the same. This would not be any more difficult than the work of regulating the feed water to a battery of steam boilers.—Engineering.

PIANOS IN FRANCE.

CONSUL-GENERAL ROBERT P. SKINNER, of Marseille, furnishes the following information concerning the piano trade in France and the steps that must be taken for the introduction of American pianos into that country.

The most highly regarded and expensive piano offered for sale in France bears a well-known American name, principally because it has been the concert piano of preference of a number of celebrated artists, but its price prevents it from becoming a popular instrument, in spite of its recognized superiority.

The French piano of commerce must sell at retail at from $100 to $200. It is usually an upright piano, with a range of seven octaves, or a grand piano (*piano à queue*), with a range of seven and a quarter octaves. The old-fashioned rectangular piano is no longer manufactured in this country, and is seldom seen. The favorite woods for piano cases are poplar and walnut, which are waxed and polished, instead of being highly varnished as in the United States. The cheapest woods are painted with a black enamel paint, and resemble the low-priced American standard pianos. Upright pianos sell at wholesale in this country at from $89 to $328, and at retail at from $116 to $347. Grand pianos sell wholesale at from $250 to $733, and retail at from $290 to $772. The retail dealer expects to make an average profit of $20 on upright instruments and $40 on grand pianos.

The possibility of selling American pianos in this country would depend upon the ability of the American manufacturers to overcome the French duty of $11.58 on upright and $16.40 on grand pianos. It would also be necessary for American manufacturers to send a competent representative to this market to present their claims with vigor and ability. There are numerous French pianos on sale at low prices, and they are unlikely to be displaced by efforts to sell American pianos by correspondence.

The imports and exports of pianos into and from France during the last three years were as follows:

Imports:	1905.	1906.	1907.
Description.	Number.	Number.	Number.
Upright	357	429	508
Grand	130	164	229
Total	487	593	737
Exports:			
Upright	4,497	4,836	4,457
Grand	281	316	366
Total	4,778	5,152	4,823

Judging from the comparative insignificance of the

importations of pianos into France, it seems certain that American pianos would have to be presented with particular ability in order to succeed.

ENGINEERING NOTES.

It is said that 100,000,000 ties were used by steam and street railways in one year in the United States for construction of new track and renewals. Approximately three-quarters of these were hewed and one-quarter sawed. Oak furnished more than 44 per cent and Southern pine 1/6 per cent.

The French customs returns for the first quarter of 1908 show a serious falling off in exports and imports of automobiles and motor cycles. The exports of automobiles and detached parts fell from a total of $7,637,400 for the first quarter of 1907 to $5,962,000, a diminution of 21.9 per cent. The falling off in imports is not so great, the totals for the January quarters of 1907 and 1908 being $326,200 and $273,000. The Journal des Débats remarks that there has been a big slump in motor cycles, the figures being: Exports, 1907, $41,000; 1908, $30,800. Imports, 1907, $1,200; 1908, $800.

An aerial ferry bridge of 250-foot span and 75-foot headroom, consisting of a suspension bridge carrying a track on which runs a carriage supporting a car just above high water level, has been built across the River Mersey at Warrington, England, connecting the two plants of Messrs. Joseph Crossfield & Sons. A ferry was thought impracticable because of the tidal rise and rapidity of the tidal current, and no room could be found for tunnel approaches, while a bridge of the usual type would have required still longer approaches to secure the necessary headroom. The bridge is built on the suspension type and has two 7-inch main cables carried on steel towers. Single vertical suspenders, 1¼ inch in diameter, on 10-foot centers, on each cable carry the riveted stiffening trusses and the runway channels which serve as tracks for the carriage of the suspended car. The latter has a capacity of 2½ tons.

The Manhattan Bridge will carry four railroad tracks, in addition to a wide roadway for vehicles and two footpaths for pedestrians. The suspension bridge proper, disregarding the approaches, will consist of a main span 1,470 feet long, and two side spans each 725 feet in length. The total width of the floor of the bridge will be 120 feet, as compared with the width of 85 feet of the old Brooklyn Bridge. The total pull of the four cables amounts to 30,000 tons, and to resist this exceptionally heavy anchorages are provided. The total load on each tower is 32,000 tons under the maximum possible congestion of traffic on the bridge. The area of the metal in the towers at the top is 4,400 square inches, and at the base 14,800 square inches. The maximum possible unit pressure on the steel of the towers at the base, under congestive load, is 27,500 pounds per square inch, this including both the vertical loads and the stresses due to the bending of the towers. The maximum unit stress under the reasonable ordinary working load will be 20,000 pounds per square inch. It should be explained here that the maximum congested load with four tracks crowded from end to end, the roadway a continuous jam of vehicles, and the footpath crowded with people, is 8 tons per linear foot of the bridge, and the maximum assumed working or ordinary load is 4 tons per linear foot. The suspended roadway will consist of four trusses, carried in the planes of the legs of the towers, each truss being 24 feet deep center to center of chords. Each pair of trusses will measure 28 feet from center to center, with a spacing of 40 feet between the inside truss. The four railroad tracks will be carried, two of them on the lower, and two of them on the upper, deck of the trusses. The two footpaths, each 10 feet wide, will be carried on the outside of the outer trusses on cantilever extensions of the floor beams. The central roadway for vehicles, 35 feet wide, will occupy the center of the bridge on the level of the lower deck of the trusses. A novel feature will be the use of nickel steel in the upper and lower truss chords, which will be subjected to a working stress of 40,000 pounds per square inch. The nickel steel rivets will be subject to a working stress of 20,000 pounds per square inch. In spite of the higher cost of the nickel steel, the saving in weight will be such as to make the trusses actually cheaper than if they were built entirely of ordinary structural steel. The weight of steel in the superstructure from anchorage to anchorage, exclusive of the cables, is 10,500 tons of carbon steel and 8,000 tons of nickel steel. The weight of the cables is 6,300 tons, and the total weight of steel in the whole bridge, including anchor chains, cables, towers, and suspended span, is 42,000 tons. In spite of the great weight and carrying capacity of the bridge, it will, in its completed form, be characterized by much of the delicacy and grace of appearance which has made the Brooklyn Bridge so justly famous, and the absence of which renders the Williamsburg Bridge one of the ugliest structures of its kind ever erected.

ELECTRICAL NOTES.

A large electrical generator while being tested at a works in Germany, suddenly burst with disastrous effect. Large portions of the machinery flew in every direction with such force that the building was completely wrecked, the roof falling down upon a number of workmen, killing three and severely injuring fifteen others.

Experiments by the Danish government with windmills for electric power generation for industrial and agricultural purposes have demonstrated that those of the four-wing type are the most successful in operation because they give the most power for a given area. With a wind velocity of 20 feet per second (13½ miles per hour) one horse-power may be developed on 65 square feet of surface. With a velocity of 26 feet the power is doubled.

On the system of electric traction in use on the Vesuvius Railway the trains are usually made up of two cars, each carrying two 75-horse-power motors, electrically connected as follows: The main cable from the trolleys on each car is continued on to each of the platforms, where it ends in a socket. In the cable from the main conductor to the motors is placed a shunt, which is connected to two sockets fixed on the platform of each car. Two other conductors run the entire length of both cars, connected to the ammeter leads on the other car. The two trolleys are in parallel, but the regulating magnets and brake equipment are separate. Each motorman watches the readings of the ammeter connected in the circuit of the other car. These readings insure simultaneous operation. The motorman on the leading car is in charge, and all his movements are followed by the man on the second car.

An interesting form of current meter for electric lighting is made by a German firm. The use of the metallic filament lamps now reduces the cost of electric lighting considerably, and it is within reach of all. At the same time the new meter which is devised by M. Mordez-Fricker and constructed by the Rittershausen firm of Cassel, does not cost much more than an ordinary meter, and it has the advantage of operating on the coin-in-the slot principle, so that the consumer can use as much current as he needs. Owing to these two circumstances, some of the German electric plants have had an increase of 25 or 30 per cent in their subscribers. The apparatus consists of a glass vessel having an electrolytic bath. Above it is a thin copper strip forming the anode and it plunges more or less into the liquid. The cathode is formed by a fixed plate placed in the bath. The apparatus is mounted in series with the lamps, etc., so that all the current passes through it. The current slowly dissolves the metal of the strip and it is precipitated upon the cathode, and the length of the anode which dips into the liquid corresponds to the sum which the consumer has introduced in advance into the apparatus, such as a 25 cent piece. This is easily carried out by a mechanism which unrolls a quantity of the strip from a drum on which it is carried. As soon as the part of the strip corresponding to the payment is dissolved, the strip is out of contact with the liquid and the current no longer passes. No motor or clockwork mechanism is needed in this case, and there is only a lever to which the consumer gives half a revolution at the same time that he places the coin in the slot. As the same number of ampere-hours always dissolves the same amount of copper, the consumer always secures the proper amount.

We have already had occasion to illustrate the apparatus which was devised by the German inventor, Dr. Korn, for transmitting photographs to a distant station. Not long since, two very handsome instruments have been completed at the Carpentier establishment at Paris, and M. Carpentier states that they were ordered by an American journal. It will be remembered that the transmitter and receiver each have an upright cylinder which is rotated and moved vertically somewhat like a phonograph cylinder. In the present case the complete apparatus includes a transmitter and a receiver which are mounted together, and there is a duplicate apparatus for the other end. These are now connected by a short wire and the last experiments which were made showed excellent results in the transmission of the photographs. The time is about twelve minutes for a complete transmission, and the film is removed from the apparatus and developed. A dark box which contains the entire cylinder and can be removed at once makes this easy to carry out. As a whole, the apparatus has the form of a table of some length, with the electric motor placed on a shelf underneath. On the table are mounted the transmitter and receiver placed side by side and all inclosed. The different parts are readily accessible. One point to be noted is that the shutter which controls the light beam of the receiver according to the current of the line coming from the selenium cell, is formed of a light metal piece suspended on two stretched wires between the poles of an electromagnet. The piece does not rotate, but is shifted to one side more or less so as to cut off the light.

TRADE NOTES AND FORMULÆ.

Potato Starch.—Rub up 0.5 part by weight of well-washed raw potatoes on a grater and boil the pulp thus obtained for a few minutes with 3 parts of clean water. Then take it from the fire and gradually stir in 0.015 part of pulverized alum, and finally beat it up with wooden spoons until perfectly clear.

Genuine Coffee Extract.—From 1 part of ground coffee and the necessary quantity of boiling water make a decoction that after filtration consists of ½ part by weight of fluid. This with the addition of 0.2 part sugar is evaporated in a shallow dish at a temperature of at the highest 140 deg. F. to such an extent that a sample dropped on a glass plate on cooling becomes a solid mass. The fluid is then poured into molds that give the solidified pieces the form of tablets and these are wrapped in tin-foil or paraffined paper.

To Preserve Quicklime.—First put down a layer 6 to 8 inches thick of lime that has been reduced by moisture to powder on the floor of a bin (protected from moisture). On this layer pile lumps of lime and with suitable pieces of wood ram them as closely together as possible. Then cover this heap, somewhat sloped toward the edges, with a layer of lime moistened on top. The latter crumbling to powder will fill up all the interstices between the burned lime and inclose it so that the unmoistened lime will be protected against the entrance of air and moisture.

To Prevent the Detachment of Lime Finish.—*a.* In making the finishing mortar, a gravel free from dust and loam must be used, and this after rough application to the well-moistened wall must not be rubbed smooth, but left rough. *b.* For smooth finish, use so-called long cement mortar, lime paste 1 part, cement 2 to 4 parts, sand 6 to 12 parts. Over this a coating of a solution of 3 parts of green vitriol in 3 parts of water may be given (up to four coats). After this two coatings with 5 per cent soap water, then dry with cloth or brush.

Varnishes for Horn Work.—*a.* Colorless: 1 part of the finest washed sandarac is dissolved in 9 parts of 96 per cent alcohol in a glass bottle, being frequently shaken, and after solution 0.16 of Venice turpentine made fluid and slowly added to the sandarac solution, stirring meanwhile. The varnish thus prepared is poured into glass bottles, in which it clarifies and it is kept in the light until needed. *b.* Brown: Dissolve 1 part of the finest orange shellac in 14 parts of 96 per cent alcohol and filter the solution through filter paper. Then 0.16 of Venice turpentine is made fluid over an open fire and the shellac solution slowly stirred in. *c.* Dark Brown: Proceed exactly as above described with 1.5 parts of ruby shellac, 17 parts of 96 per cent alcohol, and 0.16 part of Venice turpentine. *d.* Yellow: A shellac solution is prepared, as in the case of the brown varnish and to this is added 0.5 part ground curcuma root (turmeric) which is allowed, with frequent shakings, to extract for several days. Then filter again through blotting paper and add the thick Venice turpentine. *e.* Brownish Red (for tortoise shell imitation): 1 part of fine dragon's blood in sticks is pounded fine so that it appears as a fine powder and over this in a bottle is poured 9 parts of 96 per cent alcohol, then with frequent shaking allow the alcohol to dissolve as much of the dragon's blood as it will take up, filter the dark red-colored solution through filter paper and dissolve in it 0.75 part of fine orange shellac. The solution is expedited by frequent shaking, then it is filtered and 0.3 part of Venice turpentine added to it. *f.* Fiery Red (for imitating tortoise shell): 0.5 part of fine orange shellac, 0.5 part of bleached shellac, 0.5 part of selected sandarac dissolved in 17 parts of 96 per cent alcohol, 0.02 part of diamond fuchsine added, and the red fluid filtered through blotting paper. Then in a porcelain vessel, over a fire, liquefy 0.25 part of elemi gum, stir it slowly into the varnish and keep it until wanted. *g.* Black: Dissolve 1.5 parts of orange shellac, 0.5 part of sandarac in 20 parts of 96 per cent alcohol, filter it through blotting paper, add to the solution 0.2 part of Venice turpentine, and to this 0.04 part of aniline black, soluble in alcohol, which dissolves in the varnish.

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